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Contents

Effect of sea buckthorn juice addition on the oxidative stability, physicochemical and sensory properties of soy milk mayonnaise during refrigerated storage

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Abstract

Introduction. The purpose of the present study was to investigate the antioxidant potential of the sea buckthorn juice and to explore for its use as enrichment to soy milk mayonnaise, in order to improve the color, oxidative stability and sensory quality of mayonnaise during storage.

Materials and methods. Four different mayonnaise formulations were prepared: MC (control), MBHT (made with 0.1% BHT addition), MSB3 (made with 3% sea buckthorn juice addition) and MSB6 (made with 6% sea buckthorn juice addition). Titratable acidity, pH, CIELab color values, peroxide values (PV), thiobarbituric acid reactive substances (TBARS) values and sensory attributes were determined in mayonnaise samples immediately after preparation and at two weeks intervals during the eight weeks storage period.

Results and discussion. Sea buckthorn juice had an average ascorbic acid content of 78.85 mg/100 g and an average total carotenoid content of 14.66 mg/100 g. The addition of the sea buckthorn juice resulted in the increase in redness (a^* values) as well as the decrease in lightness (L^* values) and yellowness (b^* values) of mayonnaise as compared with the control samples. During storage, the redness slightly increased in all the mayonnaise samples, while lightness decreased. The oxidative stability of the mayonnaises was improved through storage by enrichment with sea buckthorn juice, as indicated by PV and TBARS values. After 8 weeks of storage, PV and TBARS values of MSB3 (12.45 meq·kg^{-1} and 1.35 mg·kg^{-1}, respectively) and MSB6 (12.80 meq·kg^{-1} and 1.87 mg·kg^{-1}, respectively) were significantly lower compared to control sample (34.20 meq·kg^{-1} and 2.18 mg·kg^{-1}, respectively), indicating the protective effect of antioxidants from sea-buckthorn juice against lipid oxidation in mayonnaise. Except for color, the sensory attributes of mayonnaise were not significantly ($p<0.05$) affected by the addition of sea buckthorn juice. In terms of color, the highest score was recorded for MSB3 sample throughout the storage period. A syneresis was observed in the last three weeks of the storage period in the samples with added sea buckthorn juice, stronger in samples with 6% addition.

Conclusions. The improved oxidative stability and sensory properties of the mayonnaise samples obtained with 3% sea buckthorn juice addition demonstrate the potential of the sea buckthorn juice to be added in mayonnaise for industrial purpose.

Introduction

Mayonnaise is a semisolid low-pH oil- in- water (O/W) emulsion made of the dispersed phase represented by the oil (70-80%), the aqueous phase containing various components such as NaCl, sugar, mustard, lemon juice or vinegar, and the emulsifier at the interface [1,2]. Owing to its high emulsifying capacity and sesory attributes, egg yolk is the most widely utilized emulsifying agent in mayonnaise [3,4]. However, egg yolk is an animal protein source containing several allergens and one of the most important dietary sources of cholesterol [5,6].

The consumption of mayonnaise has been increasing worldwide but health consciousness regarding this food product, due to its high cholesterol and fat content, have shifted the demand of consumers towards more healthier mayonnaise- like emulsions [7]. As a result, different attempts have been carried out to use another emulsifier in addition to egg yolk, or to completely replace this key ingredient in order to develop low cholesterol sauces with similar characteristics to real mayonnaise [3,8]. During the last years, an array of plant proteins (e.g. proteins from soy, sunflower, pea, tomato seed, wheat, white lupin and faba bean) have been tested to stabilize oil-in-water emulsions and to reformulate mayonnaise in order to meet consumer demands [4,7,9]. Vegan mayonnaise is the most tested product in studies on the effectiveness of vegetable ingredients to substitute the egg's properties [9]. Soy contains high quality proteins, essential fatty acids and beneficial compounds for human health (i.e. isoflavones, folic acid and polyunsaturated fatty acids) but is low in cholesterol and saturated fat. It provides functional physical properties within food systems and a wide range of health benefits, such as reducing the risk of heart disease, reducing breast cancer risk, slowing or preventing the progression of several cancers and alleviating menopausal symptoms [10,11].

Söderberg [12] investigated the potential of soy protein as egg replacer in vegan foods and found that soy protein has nutritional and emulsifying properties that are similar to that of egg protein. Puppo et al. [13] evaluated the feasibility of replacing common emulsifiers with soy protein isolates in low-calorie salad dressings while Garcia et al. [14] studied the influence of powdered soy milk as an emulsifier to obtain a dressing-type mayonnaise.

The drawbacks with using soy proteins in foods are their content of anti-nutritional factors that negatively affect their digestibility and their distinct "beany" flavor due to the content in saponins, ketones and aldehyde compounds, that may contribute to a reduced consumer acceptance for food products [9].

Mayonnaise, like other high- oil containing foodstuffs, is susceptible to lipid oxidation resulting in the formation of free radicals (R·), lipid peroxyl radicals (ROO·) and hydroperoxides (ROOH) as primary oxidation products. Further, the hydroperoxides decompose to aldehydes, ketones, alcohols, hydrocarbons, volatile organic acids and epoxy compounds, known as secondary oxidation products, which are responsible for undesirable off-flavours of the oil [2,15] and consequently decrease the shelf life of mayonnaise [16]. The lipid oxidation reactions are generally initiated at the interface between the oil and water phases, where pro-oxidants can react with the hydroperoxides located at the surface of the oil droplets [17]. Synthetic antioxidants such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) and ethylene diamine tetraacetic acid (EDTA) are widely used in mayonnaise to prevent rancidity. Although synthetic antioxidants are more effective at low doses, naturally occurring antioxidants may replace synthetic antioxidants in some cases because they are generally recognized as safe [18]. In addition, these compounds could also have health-promoting benefits which may be desirable for consumers [2,4].

Sea buckthorn (*Hippophaë rhamnoides* L.) is a deciduous spiny shrub widely distributed in various regions of Asia, Europe and North America, that produces orange, red or yellow berries, and has substantial agricultural, ecological, nutritional, medicinal and ornamental value [19,20]. Sea buckthorn berries are the most important part of the plant, being traditionally known for their nutritional and medicinal value. The use of sea buckthorn berries as a natural food ingredient is increasingly gaining popularity nowadays due to their nutraceutical properties and high antioxidant contents [20,21].

Juice extracted from sea buckthorn fruits provides a nutritious beverage, very high in natural antioxidants, especially in ascorbic acid, carotenoids, tocopherols, and flavonoids [20]. It contains also other nutrients and bioactive substances including vitamins, omega-3 fatty acids, free amino acids, dietary minerals, β-sitosterol and polyphenolic acids [22,23].

The objective of this study was to evaluate the addition of sea buckthorn juice in soy milk mayonnaise for improving its oxidative stability during storage for up to 8 weeks. The effect of sea buckthorn juice on the color parameters and sensory characteristics of prepared mayonnaise were also studied.

Materials and methods

Sea buckthorn juice

Fresh sea buckthorn fruits were purchased from a local market in Craiova, Dolj county, South-West Romania. The fruits were frozen and stored in -20°C until use. The frozen sea-buckthorn berries were washed, thawed to room temperature and hand-crushed. The juice was pressed out using a conventional juice press and filtered through sterile gauze to remove residual impurities.

Materials and chemicals

All ingredients used to prepare the mayonnaise, such as refined sunflower oil, soy milk, salt, lemon juice, and mustard were purchased from a local supermarket in Craiova, South-West Romania. Butylated hydroxytoluene (BHT), thiobarbituric acid, potassium persulfate, trichloracetic acid, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) and malondialdehyde were obtained from Sigma-Aldrich (St. Louis, Missouri, USA). All other chemicals used were of analytical grade and purchased from Merck (Darmstadt, Germany).

Preparation of mayonnaise

The control recipe contained the following ingredients in percentage (w/w): soy milk 30.8, sunflower oil 61.5, salt 1.5, mustard 3.1 and lemon juice 3.1. The mayonnaise was made in a one-step procedure. All the ingredients were mixed together for 2 min, using a standard mixer (Moulinex, DFC3, France). Through this formulation, a mayonnaise product with stable emulsion and whithout syneresis was produced.

Four different mayonnaise formulations were prepared: MC (control), MBHT (made with 0.1% BHT addition), MSB3 (made with 3% sea buckthorn juice addition) and MSB6 (made with 6% sea buckthorn juice addition). The sea buckthorn juice was added along with the other ingredients. Mayonnaise samples were packed in 500 ml disposable plastic containers, wrapped externally with aluminum foil to exclude light, and stored in refrigerator (4 °C) for eight weeks. Three different batches for each formulation were prepared.

Titratable acidity (TA), CIELab color values, peroxide values (PV), thiobarbituric acid reactive substances (TBARS) and sensory attributes were determined in mayonnaise samples immediately after preparation and at two weeks intervals during the storage period (8 weeks).

Total carotenoid content

Total carotenoid content of the sea buckthorn juice was determined spectrophotometrically as described by Lee [24], with some modifications. The juice samples (1 g) were dissolved in 25 ml of n-hexane-acetone-ethanol (v/v/v: 50:25:25) and placed on a shaker at 200 rpm at room temperature. After 10 min, the mixture was centrifuged at 4500 g for 5 min. The supernatant was collected and made to a volume of 25 mL with hexane. The absorbance of the hexane extract was read at 450 nm against n-hexane using a Cary 50 UV spectrophotometer (Varian, Palo Alto, CA, USA). A calibration curve of β-carotene standard solutions in n-hexane (0-100 mg/L) was used to determine the carotenoid content of the juice. The total carotenoid content was expressed as milligrams of β-carotene per 100 grams of juice.

Total soluble solids, titratable acidity and ascorbic acid content of sea buckthorn juice

The total soluble solids content was determined with a digital refractometer (Hanna Instruments, HI 96801, Romania) and the results were expressed in percentages. Titratable acidity was measured by the titrimetric method and the results were expressed as % malic acid.

The ascorbic acid content was determined using the iodometric titration [25].

pH measurement

pH values of mayonnaise samples were measured at 20 °C with a Hanna pH meter HI255 (Hanna Instruments, Padova, Italy) using a 10% dispersion of mayonnaise in distilled water.

Titratable acidity

Titratable acidity (TA) of mayonnaise samples was determined by titration method using 0.1 N NaOH using phenolphthalein (1% in 95% ethanol) as an endpoint indicator. Results were converted to percentage of acetic acid according to AOAC method 935.57 [26].

Peroxide value

Peroxide value was determined as follows: 5 g of sample was dissolved in 30 mL chloroform: acetic acid (1:2, v/v) in a conical flask. When the sample was completely dissolved, 0.5 ml of saturated potassium iodide solution was added. After standing for 1 min in dark, 50 mL of distilled water and 3 drops of 10% starch solution were added. The liberated iodine was titrated with 0.1 N sodium thiosulphate until the solution turn colorless. The blank sample was prepared without the addition of oil sample, and peroxide value was calculated based on equation below:

$$(S - B) \times f \times N \times 1000/W$$

where S – volume of sodium thiosulfate 0.1 used in sample titration, mL, B – volume of sodium thiosulfate 0.1 used in blank titration, mL, f – factor of sodium thiosulfate solution, dimensionless, N – normality of sodium thiosulfate solution, dimensionless, W= weight of oil sample, g.

Peroxide value was expressed as milliequivalents of active oxygen per kilogram of sample.

Thiobarbituric acid reactive substances values

TBARS values were determined spectrophotometrically as described by Witte et al. [27] with slight modifications. For extraction, five grams of mayonnaise sample were homogenised in a vortex with 12.5 ml of 20% trichloroacetic acid then transferred to a 25-ml volumetric flask and dilluted up to the volume with cold distilled water. After filtration, 5 ml of filtrate were mixed with 5 ml of 0.02 M 2-thiobarbituric acid and heated at 100 °C for 35 min. After cooling, the absorbance was recorded at 532 nm with a Cary 50 UV spectrophotometer (Varian, Palo Alto, CA, USA). The results were calculated from the standard curve of 1,1,3,3-tetraethoxypropane and expressed as milligrams of malondialdehyde (MDA) per kilogram of sample.

Color measurement

The color of mayonnaise samples was evaluated by measuring the L^* (lightness), a^* (redness/greenness), and b^* (yellowness/blueness) parameters of the CIE$L^*a^*b^*$ system using a PCECSM1 colorimeter calibrated against a white standard. The analysis was performed on three samples from each formulation with five readings for each sample.

Sensory evaluation

Sensory evaluation was conducted on the mayonnaise samples after preparation as well as at two weeks intervals during the storage period (8 weeks) by ten panelists consisting of graduate students and staff members of the Department of Food Science and Technology, University of Craiova. The test was performed on a nine-point hedonic scale, with 1 = extremely dislike and 9 = extremely like. The sample presentation order was randomized and water was provided between samples to cleanse the palate. Before each session, the panelists were trained on each attribute, the hedonic scale used, and what they need to consider during the evaluation.

Statistical analysis

All experiments were run in triplicate and results are reported as mean±standard deviation. In order to assess the effects of formulations and storage time, data were subjected to the analysis of variance (ANOVA) and Duncan's multiple-range test ($P<0.05$) using Statgraphics Centurion XVI software (Statgraphics Technologies, Warrenton, USA).

Results and discussion

Compositional characteristics of sea buckthorn juice

The directly squeezed sea-buckthorn juice had a sour-sweet and astringent taste and a smell similar to that of the fresh berries. As observed in a previous study, the juice was turbid as a result of the presence of both insoluble solids and oil droplets suspended in the aqueous juice [28]. Titratable acidity, soluble solids content, ascorbic acid content and total carotenoid content of sea-buckthorn juice are presented in Table 1. The variety, maturity, growing location, climate and method of extraction are the main factors affecting the chemical composition of sea buckthorn berries. Large variations in concentrations of acids have been reported in previous studies, but all agreed that malic acid is the dominant organic acid in sea buckthorn juice [29,30]. An average titratable acidity of 7.85% was found in our study, in good agreement with the results previously reported by Beveridge et al. [29], but much lower than the results reported by Seglina et al. [31]. A large variation in content of soluble solids has been reported in previous studies (9.3–22.74%) and it was attributed mainly to the seasonal variation of composition [29]. An average soluble solids content of 9.32% was found in our study, in good agreement with the results reported by Seglina et al. [31].

Table 1

Titratable acidity, soluble solids content, ascorbic acid content and total carotenoid content of sea-buckthorn juice

	Sea buckthorn juice
Titratable acidity (% as citric acid)	7.85 ± 0.35
Soluble solids (%)	9.32 ± 0.24
Ascorbic acid content (mg/100 g)	98.85 ± 3.24
Total carotenoid content (mg/100 g)	14.66 ± 0.56

Sea buckthorn juice is a valuable source of antioxidants, and vitamin C is the dominant antioxidant [20]. The average ascorbic acid content found in the sea buckthorn juice used in this study was 98.85 mg/100 g. Previous studies revealed extensive variations in vitamin C content, ranging from 28 to 310 mg/100 g in the berries from the European subspecies of *H. rhamnoides* [20,32]. The sea buckthorn juice had an intense orange color due to its high total carotenoid content (14.66 mg/100 g).

CIELab color values of mayonnaise

BHT determined a significant decrease in yellowness (b* value) of mayonnaise samples while the addition of sea buckthorn juice resulted in the increase in redness (a* value) as well as the decrease in lightness and yellowness of mayonnaise as compared with the control samples. Similar results have been reported by Altunkaya et al. [33] in a study on the oxidative stability and chemical safety of mayonnaise enriched with grape seed extract. MSB6 samples presented the highest a* values followed by MSB3 samples, while no significant differences were found between the a* values of MC and MBHT samples. The increase of the redness in MSB3 and MSB6 samples might be due to the high content of carotenoid pigments in the sea buckthorn juice.

Changes in lightness (L*), redness (a*), and yellowness (b*) of mayonnaise samples during 8 weeks storage at 4°C are shown in Table 2. The redness slightly increased during storage in all the mayonnaise samples, while lightness decreased. At the end of storage, MSB6 samples recorded the highest a* values and the lowest L* values, followed by MSB3 samples.

Table 2

Effect of storage on CIELab color values of mayonnaise samples

Time (weeks)	MC	MBHT	MSB3	MSB6
		L*		
0	85.22 ± 0.71^{aC}	85.81 ± 0.87^{abB}	86.83 ± 0.11^{cC}	86.54 ± 0.62^{bcC}
2	82.84 ± 1.77^{A}	84.34 ± 0.91^{A}	83.93 ± 1.27^{B}	83.36 ± 1.53^{B}
4	84.22 ± 1.41^{aBC}	86.42 ± 0.77^{cB}	85.39 ± 0.99^{bcBC}	84.54 ± 1.54^{abB}
6	82.96 ± 1.17^{abA}	83.96 ± 1.95^{bA}	81.09 ± 3.90^{aA}	83.53 ± 1.23^{bB}
8	83.34 ± 1.09^{bAB}	83.38 ± 1.06^{bA}	81.21 ± 2.33^{abA}	79.75 ± 3.82^{aA}
		a*		
0	-1.14 ± 0.11^{aA}	-1.06 ± 0.05^{aAB}	-0.54 ± 0.02^{bA}	-0.21 ± 0.08^{cA}
2	-1.10 ± 0.04^{aA}	-1.18 ± 0.07^{aA}	-0.57 ± 0.081^{bA}	-0.22 ± 0.18^{bA}
4	-0.93 ± 0.09^{aB}	-0.97 ± 0.067^{aB}	-0.34 ± 0.13^{bB}	0.10 ± 0.13^{cC}
6	-1.08 ± 0.09^{aA}	-1.11 ± 0.16^{aA}	-0.40 ± 0.14^{bB}	-0.10 ± 0.03^{cB}
8	-0.79 ± 0.08^{aC}	-0.59 ± 0.23^{aC}	-0.01 ± 0.09^{bC}	0.29 ± 0.12^{cD}
		b*		
0	13.29 ± 0.23^{dC}	10.90 ± 0.14^{aC}	12.07 ± 0.12^{bC}	12.39 ± 0.29^{cB}
2	13.13 ± 0.22^{dBC}	10.47 ± 0.33^{aAB}	11.21 ± 0.55^{bA}	12.04 ± 0.39^{cA}
4	12.89 ± 0.19^{dB}	10.55 ± 0.18^{aB}	11.58 ± 0.20^{bB}	12.43 ± 0.21^{cB}
6	12.24 ± 0.50^{cA}	10.35 ± 0.10^{aA}	11.23 ± 0.45^{bA}	11.94 ± 0.35^{cA}
8	12.45 ± 0.41^{dA}	10.79 ± 0.21^{aC}	11.36 ± 0.43^{bAB}	12.11 ± 0.26^{cA}

MC – control mayonnaise;
MBHT – mayonnaise made with 0.1% BHT addition;
MSB3 – mayonnaise made with 3% sea buckthorn juice addition;
MSB6 – mayonnaise made with 6% sea buckthorn juice addition;
L^* – lightness color coordinate, a^* – redness/greenness color coordinate;
b^* – yellowness/blueness color coordinate;
Different lowercase letters indicate significant difference at $p<0.05$ level between different formulations, while different uppercase letters are indicative of the same within each formulation during the storage period; Data are expressed as mean±standard deviation.

The darkening of mayonnaise samples during storage may be attributed to the non-enzymatic browning reactions having as substrate the carbonyl compounds generated during lipid oxidation, as well as to the brown-colored oxypolymers produced via polymerization from the lipid oxidation derivatives [34].

Titratable acidity, pH, peroxide values and thiobarbituric acid reactive substances values of mayonnaise

The pH and titratable acidity of soy milk mayonnaise samples recorded during 8 weeks of storage are given in Table 3. The mean pH value was 4.57 in the freshly prepared control

mayonnaise samples. Addition of sea buckthorn juice determined a significant decrease of the pH value and an increase of the titratable acidity but the differences between samples within each formulation during the storage period were not significant.

The peroxide value (PV) determines the primary oxidation products (hydroperoxides) formed during the autoxidation of unsaturated lipids and it is an indicator of the initial stage of lipid oxidation or oxidative rancidity [35]. The peroxide values of control and experimental mayonnaise samples during 8 weeks storage are presented in Table 3.

Table 3

Effect of storage on pH, titratable acidity, peroxide values and thiobarbituric acid reactive substances of mayonnaise samples

Time (weeks)	MC	MBHT	MSB3	MSB6
pH				
0	4.57 ± 0.15^{bc}	4.64 ± 0.11^{c}	4.30 ± 0.14^{ab}	4.04 ± 0.17^{a}
2	4.63 ± 0.21^{b}	4.65 ± 0.19^{b}	4.29 ± 0.16^{ab}	4.03 ± 0.22^{a}
4	4.65 ± 0.18^{b}	4.69 ± 0.22^{b}	4.34 ± 0.20^{ab}	4.09 ± 0.21^{a}
6	4.65 ± 0.24^{b}	4.72 ± 0.16^{b}	4.35 ± 0.25^{ab}	4.12 ± 0.16^{a}
8	4.62 ± 0.20^{b}	4.75 ± 0.19^{b}	4.41 ± 0.21^{ab}	4.21 ± 0.19^{a}
Titratable acidity				
0	0.14 ± 0.02^{ab}	0.11 ± 0.01^{a}	0.15 ± 0.02^{bc}	0.18 ± 0.02^{c}
2	0.13 ± 0.01^{ab}	0.11 ± 0.01^{a}	0.15 ± 0.01^{b}	0.18 ± 0.02^{c}
4	0.13 ± 0.02^{b}	0.10 ± 0.01^{a}	0.14 ± 0.02^{b}	0.18 ± 0.01^{c}
6	0.13 ± 0.01^{b}	0.10 ± 0.01^{a}	0.14 ± 0.01^{b}	0.17 ± 0.01^{c}
8	0.12 ± 0.01^{b}	0.08 ± 0.01^{a}	0.14 ± 0.01^{b}	0.17 ± 0.02^{c}
Peroxide values ($meq\cdot kg^{-1}$)				
0	2.44 ± 0.16^{aA}	2.20 ± 0.13^{aA}	2.25 ± 0.14^{aA}	2.23 ± 0.15^{aA}
2	7.42 ± 0.32^{bB}	5.85 ± 0.27^{aB}	6.21 ± 0.28^{aB}	6.35 ± 0.35^{aB}
4	17.60 ± 0.82^{cC}	7.40 ± 0.38^{aC}	8.48 ± 0.37^{bC}	8.80 ± 0.49^{bC}
6	26.12 ± 1.24^{bD}	11.42 ± 0.57^{aD}	11.60 ± 0.52^{aD}	11.84 ± 0.58^{aD}
8	34.20 ± 1.66^{bE}	12.25 ± 0.67^{aE}	12.45 ± 0.58^{aE}	12.80 ± 0.56^{aE}
TBARS values ($mg\cdot kg^{-1}$)				
0	0.71 ± 0.04^{aA}	0.69 ± 0.04^{aA}	0.71 ± 0.04^{aA}	0.73 ± 0.03^{aA}
2	0.82 ± 0.04^{bcA}	0.72 ± 0.04^{aA}	0.75 ± 0.05^{abA}	0.85 ± 0.04^{cB}
4	0.99 ± 0.04^{bB}	0.82 ± 0.04^{aB}	0.93 ± 0.05^{bB}	0.94 ± 0.04^{bB}
6	1.45 ± 0.08^{bC}	0.97 ± 0.05^{aC}	1.05 ± 0.06^{aC}	1.35 ± 0.07^{bC}
8	2.18 ± 0.11^{dD}	1.18 ± 0.05^{aD}	1.35 ± 0.07^{bD}	1.87 ± 0.10^{cD}

MC – control mayonnaise;
MBHT – mayonnaise made with 0.1% BHT addition;
MSB3 – mayonnaise made with 3% sea buckthorn juice addition;
MSB6 – mayonnaise made with 6% sea buckthorn juice addition;
TBARS – thiobarbituric acid reactive substances;
Different lowercase letters indicate significant difference at $p<0.05$ level between different formulations, while different uppercase letters are indicative of the same within each formulation during the storage period; Data are expressed as mean±standard deviation.

After preparing the mayonnaises (day 0), the highest PV value was found in control samples (2.44 meq/kg). However, no significant differences were found between PV values of mayonnaise samples at this moment. ANOVA indicated a significant ($p<0.05$) increase in the PV value of mayonnaise with storage. The results confirmed the previous finding that PV increased gradually in control and experimental mayonnaise samples throughout the storage period [36,37]. As can be seen in Table 3, control mayonnaise showed the highest PV both after 4 weeks (17.60 meq/kg) and at the end of storage (34.20 meq/kg).

The results showed that BHT retarded the hydroperoxide formation significantly ($p<0.05$) in mayonnaise throughout 8 weeks of storage, indicating the high efficiency of BHT in retarding lipid oxidation. Peroxide values of MSB3 and MSB6 samples were lower compared to the control sample but the lowest PV values were recorded in MBHT samples (Table 3).

No significant differences were found between peroxide values of MSB3 and MSB6 samples during the storage period.

The results of the secondary lipid oxidation products as shown by the TBARS values are presented in Table 3. Storage time had a significant effect on mayonnaise oxidation, an increasing level of TBARS was observed in all samples over the storage period, indicating an increase in lipid oxidation during storage. The greatest increase in TBARS values was observed in control mayonnaise samples, followed by MSB6 and MSB3 samples while the lowest was recorded in MBHT samples.

The TBARS values in MSB3 and MSB6 samples were significantly lower ($p<0.05$) than in control samples in the last 4 weeks of storage, thus indicating the protective effect of antioxidants extracted from sea-buckthorn juice against lipid oxidation in mayonnaise. However, the strongest protective effect was observed for BHT.

Raikos et al. [15] found that carotenoids did not offer any protection against lipid oxidation, although significant amounts of α- and β- carotene and lutein/zeaxanthin were detected in the mayonnaise samples containing carrot, broccoli and onion. Kiokias et al. [38] showed that carotenoid concentration may affect, alongside carotenoid and emulsion structure, the carotenoid activity in sunflower oil-in-water emulsions. They found that several carotenoid extracts (paprika, annatto and marigold preparations) containing mainly polar carotenoids, added at an active concentration of 1 g/l, exerted a strong activity against hydroperoxides and TBARS during the accelerated oxidation (60 °C) of homogenised protein-based emulsions. On the contrary, carotene preparations rich in hydrophobic α- and β-carotenes and lycopene did not significantly differ from the control emulsion. Therefore, the carotenoid structure modulated their antioxidant effect, while concentration and emulsion structure may also affect carotenoid activity in protein dispersed systems.

Sensory attributes of mayonnaise

The results of the sensory analysis of the mayonnaise samples after preparation as well as after 2, 4, 6 and 8 weeks of storage at 4 °C are shown in Table 4. Except for color, the sensory attributes of MC, MBHT, MSB3 and MSB6 samples did not differ significantly ($p<0.05$) at zero time, showing that the addition of sea buckthorn juice did not significantly influenced the taste, consistency and the overall acceptability of mayonnaise. A significant decline in all sensory attributes and overall acceptability of mayonnaise was observed during storage. A similar trend for color, aroma, taste, and overall acceptability were observed during the storage of control and lycopene-added mayonnaise [36].

In terms of color, the highest score was recorded for MSB3 sample throughout the storage period, proving that the more reddish color of the mayonnaise due to the addition of

3% sea-buckthorn juice was appreciated by the panelists. However, the deep-reddish color of MSB6 samples was less appreciated and, as a result, the overall acceptability of these samples was lower. In the last part of the storage period (the last 3 weeks) there was a process of syneresis in the samples with added sea buckthorn juice, stronger in samples with 6% addition. This phenomenon is probably due to the higher acidity values and it explains the decrease of the scores regarding consistency and general acceptability of the MSB3 and MSB6 samples as compared with control and MBHT samples.

Table 4

Effect of storage on sensory attributes of mayonnaise samples

Time (weeks)	MC	MBHT	MSB3	MSB6
Color				
0	8.17 ± 0.39^{aE}	7.92 ± 0.51^{aC}	8.58 ± 0.51^{bD}	8.25 ± 0.45^{abD}
2	7.75 ± 0.45^{aD}	7.67 ± 0.49^{aBC}	8.25 ± 0.45^{bCD}	7.83 ± 0.39^{aC}
4	6.75 ± 0.62^{aC}	7.25 ± 0.45^{bAB}	7.92 ± 0.51^{cBC}	7.00 ± 0.43^{abB}
6	6.25 ± 0.45^{aB}	7.17 ± 0.39^{bA}	7.58 ± 0.51^{bAB}	6.58 ± 0.67^{aA}
8	5.83 ± 0.39^{aA}	6.83 ± 0.72^{bA}	7.17 ± 0.58^{bA}	6.25 ± 0.45^{aA}
Taste				
0	8.50 ± 0.52^{aD}	8.42 ± 0.51^{aD}	8.58 ± 0.51^{aD}	8.17 ± 0.58^{aD}
2	8.25 ± 0.45^{abD}	8.25 ± 0.45^{abD}	8.42 ± 0.51^{bCD}	7.92 ± 0.29^{aCD}
4	7.67 ± 0.49^{abC}	7.83 ± 0.39^{abC}	8.00 ± 0.43^{bC}	7.58 ± 0.51^{aC}
6	6.83 ± 0.39^{aB}	7.42 ± 0.51^{bB}	7.50 ± 0.67^{bB}	6.75 ± 0.45^{aB}
8	5.83 ± 0.39^{aA}	6.75 ± 0.45^{bA}	6.50 ± 0.52^{bA}	5.58 ± 0.51^{aA}
Consistency				
0	8.75 ± 0.45^{aD}	8.67 ± 0.49^{aD}	8.83 ± 0.39^{aD}	8.50 ± 0.52^{aD}
2	8.58 ± 0.51^{aD}	8.50 ± 0.52^{aD}	8.58 ± 0.51^{aD}	8.25 ± 0.62^{aD}
4	7.83 ± 0.39^{aC}	7.92 ± 0.51^{aC}	8.00 ± 0.60^{aC}	7.67 ± 0.65^{aC}
6	6.92 ± 0.29^{bB}	7.00 ± 0.43^{bB}	6.83 ± 0.58^{bB}	6.42 ± 0.51^{aB}
8	5.92 ± 0.51^{bcA}	6.33 ± 0.49^{cA}	5.58 ± 0.51^{abA}	5.17 ± 0.72^{aA}
Overall acceptability				
0	8.42 ± 0.51^{aD}	8.33 ± 0.49^{aD}	8.50 ± 0.52^{aC}	8.25 ± 0.62^{aD}
2	8.25 ± 0.45^{aD}	8.17 ± 0.39^{aCD}	8.33 ± 0.49^{aC}	8.08 ± 0.51^{aD}
4	7.75 ± 0.45^{abC}	7.92 ± 0.29^{abC}	8.08 ± 0.67^{bC}	7.58 ± 0.51^{aC}
6	7.00 ± 0.43^{abB}	7.33 ± 0.49^{bcB}	7.50 ± 0.67^{cB}	6.58 ± 0.51^{aB}
8	6.33 ± 0.49^{bA}	6.75 ± 0.45^{bA}	6.42 ± 0.67^{bA}	5.67 ± 0.49^{aA}

MC – control mayonnaise;
MBHT – mayonnaise made with 0.1% BHT addition;
MSB3 – mayonnaise made with 3% sea buckthorn juice addition;
MSB6 – mayonnaise made with 6% sea buckthorn juice addition;
Different lowercase letters indicate significant difference at $p<0.05$ level between different formulations, while different uppercase letters are indicative of the same within each formulation during the storage period; Data are expressed as mean±standard deviation.

Conclusions

1. The mayonnaise enriched with carotenoids through sea buckthorn juice addition exhibited a good oxidative stability during 8 weeks of storage as indicated by lower peroxide values and thiobarbituric acid reactive substances values.
2. Evaluation of all sensory attributes showed that mayonnaise made with 3% sea buckthorn juice addition was the most favourable sample and had the highest scores during 4 weeks of storage. However, there was no significant differences in all attributes among mayonnaise made with 3% sea buckthorn juice addition and mayonnaise made with 0.1% BHT addition ($p>0.05$). Both after 4 weeks and 8 weeks of storage, the lowest scores were given to the control sample for all the sensory properties, which was probably due to the darkening as well as to the off-flavors and off-odors generated in the deteriorative reactions of lipids that occured during storage. This was in accordance with the higher increase of peroxide values and thiobarbituric acid reactive substances values in this sample, indicating that lipid oxidation proceeded to a greater extent.
3. Besides the nutritional aspects related to the increase of antioxidant content, the addition of sea buckthorn juice led to the improvement of the chromatic characteristics of mayonnaise which may increase consumer attractiveness and confidence.
4. By adding sea-buckthorn juice, a stable and safe vegan mayonnaise can be produced without using synthetic antioxidants.

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Some quality properties and volatile compound profile of Ardahan Tel cheese, a traditional cheese in Turkey

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Abstract

Introduction. The aim of the research was to determine the pyhsico-chemical and microbiological properties and the volatile compound profile of Ardahan Tel cheese.

Material and Methods. After the cheese samples were dry matter, fat (Gerber method using Van Gulik butyrometer) salt content ($AgNO_3$ titration method) and pH analysis were made. Acidity was made according to the alkali titration method, and the results were expressed in terms of lactic acid %. Cheese samples were analyzed in terms of total aerobic mesophilic bacteria count and coliform group bacteria count, yeast and mold and lactobacilli and lactococcus count. Mass spectrometry was used for the analysis of volatile compounds of cheese samples.

Results and Conclusion. Dry matter, fat, salt, pH and acidity values of the samples varied between 46.57–59.75%, 3.69–5.12%, 9.07–10.05%, 5.13–5.62% and 0.40–0.55%, respectively. Cheese samples are included in the group of fat-free cheeses according to the classification specified in the Turkish Food Codex Cheese Communiqué.

The total aerobic mesophilic bacteria (TAMB) count of the samples ranged between 5.38–6.72 log CFU/g, lactobacilli count between 4.55–6.12 log CFU/g, lactococci count between 5.33–6.85 log CFU/g, and yeast-mold count between 2.52–3.45 log CFU/g. The number of coliform group bacteria is below the detectable limit.

A total of 38 compounds belonging to 8 chemical groups were identified: aldehydes, ketones, alcohols, acids, esters, terpenes, aliphatic hydrocarbons and aromatic hydrocarbons. Significant changes were determined in the aroma profile of Ardahan Tel cheese, depending on the manufacturer. Ethanol gave the highest level of alcohol in the samples. among the esters detected in the samples, ethyl acetate and butyl acetate gave higher levels and were determined in all samples. 9 compounds were determined in the ketone group, and the highest rate was found in 2-heptanone.

Acetic acid, butanoic acid, hexanoic acid, ethanol, 1-propanol, 1-hexanol, hexane and toluene generally gave higher values than all samples.

Conclusion. The volatile compound profile of this cheese is composed of aldehydes, ketones, alcohols, acids, esters, terpenes, aliphatic hydrocarbons and aromatic hydrocarbons. In addition to ethyl acetate also contributes significantly to the volatile compound profile.

Introduction

The abundance of the traditional product diversity of the countries is one of the indicators of their cultural wealth. Preserving this variety of products and bringing them to the industry is important both culturally and economically [1]. One of the most diverse areas in the dairy industry is cheese production. Today, there are approximately 4000 types of cheese with different flavor and texture characteristics in the world [2]. Depending on the local conditions, especially on cultural habits, and on the diversity of animal species and breeds, a variety of local cheeses are produced customarily in Turkey [3]. Local cheeses are known only in the region where they are produced, but not much in other regions. Some of these cheeses have faded into oblivion, and some of them have survived by being produced within the family and sold in local markets [4]. It has become an inevitable necessity to develop traditional products that are limited to family businesses and are about to disappear, and their characteristics to be determined and adapted to the industry [1]. Ardahan Tel cheese is one of the local cheese varieties. The nutritional value of this cheese varies depending on the fat content of the milk. Cheese contains more fat if it is made from the remaining milk by removing the fat collected on the surface after being rested before passing through a separator. In some cases, Tel cheese can be made from whole fat milk optionally [5].

In the production of Tel cheese, cow's milk is strained and kept for a certain period of time in large containers. After the fat on the surface is collected, it is left to rancid for 5-6 hours or more. Optionally, some fresh milk can be mixed into the skimmed milk. According to the amount of milk, the amount of yeast is calculated and added to the milk. It is then heated by mixing. This process continues until the curd sticks on the ladle. The cauldron where we have the curd is taken from the fire, the curd is removed and wrapped on a pole which is nailed to the wall. The cheese dough is stretched and folded on the pole and continued until the cheese assumes a string structure. The cheese, which is in the form of a string, is salted into a tin, a cube or a bagel, and then offered for consumption after the maturation period of 3–4 months. Sometimes, while the curd is hot, it is passed through the sieves to become string, and then salted, wrapped in cloths and sold. It can be consumed in fresh form or, if desired, it can be placed in cans or overalls with brine. It is matured in this way. Cheese is also known by names such as "Saçak", "Çivil", "Çeçil" or "Çekme Cheese" peculiar to the region. Yield in Tel cheese varies between 8–10% on average [5, 6].

The most important factors affecting cheese quality are characteristics such as the taste and aroma, texture and appearance of the cheese [7]. The unique characteristics of cheese are formed as a result of biochemical reactions such as glycolysis, proteolysis and lipolysis that occur during maturing. Free fatty acids released as a result of lipolysis reaction affect the taste and aroma of the cheese. It is also reported that most of the free fatty acids are precursors to many compounds, such as alcohols, esters, aldehydes, ketones, and lactones, which contribute significantly to the flavor of the cheese [8]. Free fatty acid content of cheese is affected by factors such as maturation time, microbiological activity, lipase activity, pH, temperature and salt amount [9]. The presence of short, medium and long chain fatty acids is accepted as the most important indicator after the compounds formed as a result of glycolytic and proteolytic reactions in the maturing of cheese [10, 11].

There are limited studies that investigated the physical, chemical and microbiological properties of Ardahan Tel cheese [12]. However, there is no study in the literature to determine the aroma profile of this cheese. In this research, it was aimed to determine the aroma profile and quality characteristics of Ardahan Tel cheese.

Materials and methods

Material

Cheese samples were obtained from 11 different small family businesses from Ardahan province and its villages in Turkey and brought to the laboratory under cold conditions.

Method

Preparation of samples. Sampling was made for physical, chemical and microbiological analysis from samples belonging to each manufacturer. Samples were taken for volatile compound analysis and kept at -20ºC until analyzed.

Microbiological analysis. 25 g of cheese samples taken into sterile jars for microbiological analysis were weighed under sterile conditions, and 225 ml of Ringer's solution was added and homogenized for 3 minutes. In the preparation of other dilution liquids, 1 ml was taken from the first dilution tube using sterile pipettes and transferred to sterile tubes containing 9 ml of dilution liquid.

Total aerobic mesophilic bacteria count in cheese samples (TAMB) was counted on Plate Count Agar (PCA, Merck) for 48 hours at 30-32°C, coliform group bacteria count on Violet Red Bile Agar (VRBA, Merck) for 24 hours at 35-37°C, yeast and mold count Potato Dextrose Agar (PDA, Merck) for 3-5 days at 25°C. Man Rogosa Sharpe Agar for lactobacilli count (MRS, Oxoid) in anaerobic medium at 37°C for 72 hours and M17 Agar (Merck) for lactococci count at 37 ± 1°C for 48 hours were used [13, 14] .

Physical and chemical analysis. After the cheese samples were homogenized, dry matter, fat (Gerber method using Van Gulik butyrometer) salt content ($AgNO_3$ titration method) and pH analysis were made according to the methods specified by Kurt et al [15] Acidity was made according to the alkali titration method, and the results were expressed in terms of lactic acid % [16].

Volatile compound analysis. 5 grams of sample was weighed into a 40 ml vial (Supelco, Bellefonte PA, USA), and the vial was placed in a thermal block (Supelco, Bellefonte PA, USA) and kept at 40°C for half an hour to collect volatile compounds in the headspace. For adsorption of the compounds, CAR / PDMS fiber (Supelco 75 µm, USA) was placed in a vial and kept at the same temperature for 30 min. The fiber was then injected into gas chromatography (GC, Agilent Technologies 6890N). Mass spectrometry (MS, Agilent Technologies 5973) was used as a detector in the system. DB-624 (J&W Scientific, 60 m, 0.25 mm id, 1.4 µm film) was used as column in the system. The oven temperature of GC/MS was initially kept at 40°C for 6 min, then gradually increased to 110°C at 3°C / min speed, 150°C at 4°C / min speed, 210°C at 10°C / min speed and kept at this temperature for 12 min (total processing time 56.33 min). Helium was used as carrier gas in the system with a flow rate of 1ml / min. The results were evaluated by comparing from the library of mass spectrometry (NIST, WILEY, FLAVOR), and standard materials were also used for identification. Each sample was analysed in two parallels. The results were averaged and their standard deviations were calculated.

Statistical analyses

The manufacturer was taken as a factor in the study. The results obtained were subjected to analysis of variance and the main sources of variation found important were compared with Duncan multiple comparison test [17].

Results and discussion

Physico-chemical and microbiological analysis and aroma compounds results of the Ardahan Tel cheese samples are given in Table 1, Table 2 and Table 3.

Table 1

Physico-chemical properties of Ardahan Tel cheese

Manu-facturer	Dry Matter (%)	pH	Acidity (LA%)	Salt (%)	Fat (%)
A	48.85±0.21g	5.48±0.03bc	0.45±0.01de	10.05±0.28a	5.12±0.18a
B	56.28±0.03d	5.52±002bc	0.55±0.01b	10.24±0.13bc	3.49±0.02d
C	46.55±0.01f	5.45±0.07c	0.48±0.02b	11.14±0.06bc	4.05±0.07b
D	59.75±035a	5.13±0.14e	0.40±0.01cd	10.05±0.10d	3.02±0.02c
E	45.57±0.04i	5.52±0.03bc	0.45±0.02f	9.04±0.14a	3.38±0.04d
F	56.95±0.07b	5.59±0.02bc	0.44±0.01de	9.12±0.08b	5.02±0.03a
G	50.68±0.03e	5.77±0.04a	0.42±0.02def	10.03±0.05d	4.99±0.01a
Ğ	49.83±0.01f	5.28±0.02d	0.53±0.01ef	10.13±0.09c	3.78±0.13d
H	46.89±0.01h	5.23±0.02de	0.54±0.02b	10.05±0.12a	3.01±0.01c
I	59.75±0.02a	5.56±0.01bc	0.52±0.01a	10.07±0.07bc	4.97±0.02a
İ	56.65±0.01c	5.62±0.04b	0.51±0.02bc	10.02±0.22d	4.01±0.02b
Mean	52.42±1.13	5.44±0.18	0.50±0.10	10.18±0.12	3.78±0.23

The letters a, b, c, d, e and f indicate means that significantly differ at $p<0.001$ and $p<0.01$

Table 2

Microbiological properties of Ardahan Tel cheese (log CFU/g)

Manu-facturer	TAMB	Lactobacilli	Lactococci	Yeast-Mold	Coliform
A	6.71±0.03b	5.80±0.01c	6.64±0.02b	2.65±0.02c	< 2
B	6.68±0.03b	4.62±002ı	5.54±0.01h	3.04±0.02b	< 2
C	5.76±0.02e	4.80±0.01g	5.73±0.02a	3.14±0.01f	< 2
D	6.50±0.01c	4.94±0.07f	6.85±0.02a	3.12±0.01a	< 2
E	6.39±0.02d	4.55±0.01i	6.42±0.02c	2.74±0.01g	< 2
F	5.48±0.03f	6.12±0.02a	5.33±0.01ı	2.52±0.03d	< 2
G	5.39±0.02g	5.43±0.04d	6.18±0.03d	2.81±0.03b	< 2
Ğ	6.54±0.04c	5.75±0.01c	6.05±0.03e	2.94±0.03e	< 2
H	5.38±0.01e	4.69±0.01h	5.19±0.01i	2.72±0.02h	< 2
I	7.03±0.01a	5.19±0.01e	6.60±0.01b	3.27±0.01de	< 2

The letters a, b, c, d, e, f, g, h and i indicate means that significantly differ at $p<0.001$ and $p<0.01$.

The pH value in cheese samples varied between 5.13 and 5.62 (Table 1). Similar results were obtained from the studies made on civil [18], which is in the same group with Tel cheese, Erzurum Civil (Cambaztepe et al [19] and Ardahan Çeçil [12]. However, lower pH values

(3.82-4.45) were determined in another cheese type called Çeçil cheese [20], In Bayburt Civil [21] cheese, higher pH values such as 6.07 were detected. These differences are thought to arise from the production method and production conditions.

It was determined that the acidity values (% LA) varied between 0.40-0.55% in Ardahan Tel cheese samples. Similar to the findings obtained in this study, Yangılar and Kızılkaya [12] found that Ardahan Çeçil cheese samples varied in the range of 0.43%. However, higher acidity values were determined in these types of cheese [20-22]. The amount of dry matter in cheese is an important quality parameter, and it varies depending on the raw material, production method and maturation / storage conditions [1]. As can be seen in Table 1, the amount of dry matter in Ardahan Tel cheese was determined as minimum 46.57% and maximum 59.75%. Similar results were found in Ardahan Çeçil [12] and Bayburt Civil [21] cheeses. However, lower amounts of dry matter were determined in Erzurum Civil cheese [23]. An important factor in dry matter is the fat content. In terms of fat ratio, it was found higher than other samples belonging to producers with codes A, F, G and I (Table 1). Cheese samples are included in the group of fat-free cheeses according to the classification specified in the Turkish Food Codex Cheese Communiqué (10> milk fat) [24].

Fat rates were determined by Tekinşen et al. [20] as ranging between 0.50-4.50%, by Bakırcı and Andiç [22] as between 0.10-9%, and by Yangılar and Kızılkaya [12] as between 3.66-6.25% and Arslaner and Salık [21] as between 0.50-2.60%.

Salt, which is added later in order to give flavor to the cheese and to increase its durability and to direct maturation, has an effect on the consistency and yield. It is reported that the pickling or dry salting process affects the dry matter and ash content of the cheese [23, 25]. The salt content of the samples ranged from 9.07 to 10.05% (Table 1). In other studies, on the subject, it was determined that the salt ratio showed a wide variation [12, 21, 22]. The wide variation in salt ratio is thought to be due to the water ratio of cheese and non-standard production conditions. In addition, some cheese varieties can be sold without salting after production.

Microbiological properties of the samples are given in Table 2. The total aerobic mesophilic bacteria count was determined as 5.39-7.02 log CFU/g. Similar numbers were obtained in similar cheese types [1, 12, 22, 26]. In the present study, the numbers of lactobacilli and lactococci varied between 4.55-6.12 log CFU/g and 5.33-6.85 log CFU/g respectively. As can be understood from these results, lactococci constitute an important part of the microbiota. The number of lactobacilli is also very close to the total number of bacteria in some samples. It is estimated that the differences between samples varied depending on the degree of heat treatment applied in the production as well as the maturation conditions and the amount of salt used. Generally, this cheese, which is matured and put on the market, can also be offered fresh for consumption. The results obtained show that lactic acid bacteria develop during maturation and form the dominant microbiota. Lactic acid bacteria are important microorganisms in the production and maturation of many dairy products, especially cheese. Lactic acid bacteria count was determined by Yangılar and Kızılkaya [12] as 6.96 log kob/g, by Sarı et al. [1] as 7.19 log kob/g and by Şengül et al. [26] as 5.75 log kob/g .

The yeast-mold number of the samples was found to be 2.52-3.27 log CFU/g. However, in this type of cheese, similar [12, 26] or higher [21, 22] yeast-mold numbers were also determined. The number of coliform group bacteria was found below the detectable limit in all samples. This result is thought to be due to the heat treatment applied in the production of Ardahan Tel cheese and the sensitivity of this group of microorganisms to salt [25].\

Table 3

Aroma compounds detected in Ardahan Tel cheese samples produced from cow's milk (n=11)

Volatile Compounds	KI	Manufacturer				
		A	B	C	D	E
Aldehydes						
Nonanal	1143	17.41±6.40	1.50±0.50	5.69±5.69	10.63±9.63	14.69±4.47
Ketones						
Acetone	530	2.00±0.90cd	nd	1.76±1.76cd	6.80±2.48bcd	1.80±1.80cd
2-propanone	532	0.95±0.95	8.27±6.74	nd	nd	nd
2-butanone, 3-hydroxy	645	0.53±0.53	8.80±3.77	17.32±8.11	6.29±2.63	4.13±1.88
2-pentanone	746	0.60±0.60	0.96±0.96	1.55±1.17	1.13±1.13	2.92±1.56
2-heptanone	946	0.50±0.50	22.44±6.87	47.91±12.83	1.69±0.01	7.91±4.58
Nonanone, 2-methyl	962	nd	0.50±0.50	1.31±0.31	nd	2.08±1.50
Nonanone, 3-methyl	970	2.00±1.00	9.93±8.92	7.82±7.82	1.12±0.13	1.98±0.98
Nonanone, 2,5-dimethyl	1032	nd	9.84±8.84a	8.18±7.17ab	1.38±0.14	1.50±0.50bc
2-nonanone	1130	nd	2.54±0.45b	9.77±4.59a	0.50±0.50d	1.09±0.05c
Alcohols						
Ethanol	505	40.65±0.90	15.21±2.18	35.22±2.42	62.08±1.12	39.27±3.41
1-Propanol	611	42.20±16.46	61.83±22.46	42.67±23.77	14.09±2.67	17.86±9.11
1-Butanol, 3 methyl	741	0.30±0.30b	3.70±2.03b	11.47±6.45a	2.46±1.15b	0.54±0.54b
Pentanol	765	0.73±1.04	1.20±1.70	16.35±1.29	2.63±2.20	nd
2-heptanol	954	1.05±1.05	1.20±0.19	1.26±0.16	1.96±0.74	nd
1-hexanol	1070	45.92±7.20	39.54±1.87	28.80±4.66	31.70±10.01	23.44±18.94
Phenethyl alcohol	1204	0.50±0.50	2.14±1.11	3.12±1.93	0.30±0.30	2.14±0.43
Acids						
Acetic acid	710	10.81±0.21bcd	11.04±1.19bc	4.07±0.19de	4.97±0.29cde	26.32±4.31a
Propionic acid	794	23.52±8.84a	0.50±0.50b	15.99±5.53a	nd	2.44±0.82ab
Butanoic acid	882	19.08±5.53	28.87±6.95	74.05±16.58	4.63±0.26	73.25±73.24
Hexanoic acid	1023	34.90±10.46a	10.12±0.64c	5.06±5.06d	25.03±11.93b	1.96±1.51d
Octanoic acid	1228	6.56±1.13b	4.67±1.71b	0.94±0.23b	1.59±0.36b	0.43±0.12b
Esters						
Ethyl acetat	639	15.75 ±6.63	21.77±13.11	16.61±9.29	29.09±14.33	21.73±13.58
Butyl acetate	852	2.33±3.30	3.67±5.16	1.51±2.12	1.19±1.68	0.60±0.80
Isopentyl hexanoate	1294	0.48±0.48	2.15±1.27	0.67±0.26	0.72±0.30	2.66±0.52
Terpenes						
α-Pinene	949	11.92±11.92	8.59±8.59	6.79±6.79	1.18±0.17	0.57±0.57
3-Carene	1033	20.24±20.24	12.32±12.32	6.17±6.17	1.36±1.36	nd
D-Limonene	1046	34.24±13.21a	3.50±0.50c	32.30±2.31a	2.96±0.35c	5.57±1.74c
Aliphatic Hydrocarbons						
Hexane	600	15.75±4.62	85.56±7.92	11.53±1.33	41.57±11.33	42.79±6.99
Octane	800	24.22±24.22	12.76±12.76	30.72±9.96	1.44±1.44	14.09±14.09
Decane	1000	8.53±2.53	10.54±0.72	9.45±0.45	11.06±3.38	16.38±7.69
Undecane	1100	2.82±2.00	36.95±16.34	17.65±5.80	25.09±13.44	23.05±18.01
Dodecane	1200	2.61±0.39	4.37±2.93	1.51±0.62	1.94±0.97	4.28±1.79
Aromatic Hydrocarbons						
Toluene	795	12.90±1.39ab	31.64±4.58a	29.17±3.46a	5.90±0.85b	5.92±1.18
p-Xylene	895	7.50±0.50	0.65±0.65	1.07±0.07	1.33±0.33	1.80±0.14
Benzene, 1-ethyl-3-methyl	989	1.32±1.32	1.00±0.00	1.00±0.00	1.01±0.01	1.43±0.43
Benzene, 1-ethyl-2-methyl	1063	nd	nd	nd	1.73±0.73	2.65±1.34
Benzene, 1,3,5, trimethyl	1087	16.08±5.01	5.71±5.71	45.93±28.31	32.40±3.48	15.61±11.35

Continue of Table 3

Volatile Compounds	KI	Manufacturer F	G	Ğ	H	I	İ
Aldehydes							
Nonanal	1143	14.23±8.41	0.52±0.19	1.10±0.10	0.50±0.50	nd	6.16±2.15
Ketones							
Acetone	530	nd	9.51±1.45	1.39±1.39cd	18.09±1.38a	8.56±1.26bc	13.04±0.43ab
2-propanone	532	12.01±1.60	5.74±5.74	nd	nd	5.64±5.63	nd
2-butanone, 3-hydroxy	645	9.06±3.85	15.00±14.09	nd	0.80±0.69	14.10±1.62	4.61±0.40
2-pentanone	746	4.30±2.38	nd	nd	7.32±3.37	2.04±0.00	0.70±0.70
2-heptanone	946	16.37±10.35	nd	0.50±0.50	5.54±0.63	nd	9.42±3.31
Nonanone, 2-methyl	962	nd	nd	nd	nd	nd	0.80±0.18
Nonanone, 3-methyl	970	2.41±0.71	0.90±0.92	1.08±0.08	7.02±5.02	nd	2.56±1.03
Nonanone, 2,5-dimethyl	1032	nd	0.50±0.50c	nd	nd	0.50±0.50c	1.97±1.05b
2-nonanone	1130	nd	1.00±1.00	0.50±0.50d	nd	2.54±0.45b	1.40±0.68c
Alcohols							
Ethanol	505	14.14±2.03	46.36±5.56	23.86±1.99	nd	68.69±2.07	29.98±4.38
1-Propanol	611	28.27±2.17	nd	1.07±0.47	0.93±0.93	1.00±0.00	1.00±1.00
1-Butanol, 3 methyl	741	2.75±2.71b	1.69±1.69b	nd	0.80±0.80b	14.10±1.62b	8.01±0.98b
Pentanol	765	4.74±3.24	3.59±0.01	3.97±0.21	12.05±4.98	7.37±0.59	nd
2-heptanol	954	4.45±2.81	3.63±3.63	nd	1.65±1.65	3.44±0.15	2.32±0.43
1-hexanol	1070	0.22±0.31	1.00±0.00	1.29±1.29	nd	0.77±0.77	1.63±0.86
Phenethyl alcohol	1204	1.04±1.04	nd	0.99±0.19	4.90±3.07	1.42±0.42	5.19±3.46
Acids							
Acetic acid	710	9.73±1.97bcd	4.22±4.21cde	12.58±0.79b	1.72±0.42e	5.20±0.84cde	4.70±0.31cde
Propionic acid	794	nd	nd	1.22±0.00ab	nd	nd	1.49±0.11ab
Butanoic acid	882	4.67±4.67	15.62±0.60	7.37±0.54	1.36±1.36	9.22±093	62.98±42.97
Hexanoic acid	1023	12.58±5.93	34.92±3.09a	34.76±9.64a	18.48±8.48c	25.03±11.93b	12.58±9.93c
Octanoic acid	1228	15.31±2.34a	13.01±3.02a	2.03±0.40b	7.98±0.36b	0.12±0.12b	4.71±1.14b
Esters							
Ethyl acetate	639	26.88±16.25	5.91±0.61	4.86±0.40	4.89±0.55	36.56±1.97	12.41±0.41
Butyl acetate	852	4.24±4.50	5.22±0.17	3.35±0.44	1.79±0.69	1.29±1.77	1.61±0.69
Isopentyl hexanoate	1294	0.75±0.75	nd	0.24±0.24	0.43±0.43	0.38±0.38	0.76±0.21
Terpenes							
α-Pinene	949	nd	nd	nd	nd	nd	3.09±1.37
3-Carene	1033	10.28±7.40	3.95±3.95	nd	1.30±0.30	1.43±0.43	5.28-2.18
D-Limonene	1046	15.97±3.77b	2.74±2.74c	1.60±0.09c	2.78±0.49c	2.04±0.04c	0.58±0.04c
Aliphatic Hydrocarbons							
Hexane	600	36.38±9.88	27.38±2.07	82.64±16.10	70.07±10.93	47.99±37.69	74.50±5.30
Octane	800	1.09±1.09	0.91±0.91	3.90±1.88	nd	1.63±1.63	nd
Decane	1000	6.88±3.50	5.06±5.06	3.59±1.14	7.10±0.62	nd	8.08±1.04
Undecane	1100	2.40±0.23	0.50±0.50	1.59±0.41	1.48±0.20	1.56±0.41	1.00±0.00
Dodecane	1200	4.71±0.40	0.70±0.70	1.80±0.38	1.44±0.44	1.18±0.38	2.26±0.40

Continue of Table 3

Volatile Compounds		Manufacturer					
	KI	F	G	Ğ	H	I	İ
Aromatic Hydrocarbons							
Toluene	795	11.80±1.67ab	2.48±0.19b	1.69±0.05b	1.98±0.78b	3.50±0.06b	1.97±0.22b
p-Xylene	895	1.92±0.92	2.50±2.50	nd	1.32±0.22	0.55±0.55	1.06±0.25
Benzene, 1-ethyl-3-methyl	989	5.11±1.01	0.50±0.50	nd	nd	1.00±0.00	1.13±0.32
Benzene, 1-ethyl-2-methyl	1063	3.50±3.50	0.79±0.79	1.00±0.00	0.50±0.50	1.30±0.30	1.04±0.36
Benzene, 1,3,5, trimethyl	1087	nd	0.52±0.52	nd	0.50±0.50	2.05±1.05	1.67±1.67

The letters a,b,c,d and e indicate means that significantly differ *at* $p<0.01$ and $p<0.05$;
nd: not detected

A total of 38 compounds were detected, including one compound in the aldehydes group, 9 in the ketone group, 7 in the alcohol group, 5 in the acid group, 3 in the ester group, 3 in the terpene group, 5 in the aliphatic hydrocarbon group, and 5 in the aromatic hydrocarbon group (Table 3).

Cheese flavor is one of the most important criteria determining the choice and acceptance of consumers, and it is a complex mixture of hundreds of volatile compounds that do not affect the taste of cheese alone [27].

The aroma of a cheese variety can be thought of as a result of a certain balance between volatile compounds produced during cheese making [28]. It is stated that the basic flavor of cheese consists of the complex balance of non-volatile and volatile substances that are formed as a result of microbiological and biochemical reactions arising from the raw material of the milk, processing stages and maturation [29].

Milk fat is very important for the characteristic cheese flavor because it undergoes various reactions such as hydrolysis, oxidation and esterification and produces FFA, lactones, esters, and ketones that contribute to the flavor of the cheese. Free fatty acids (FFAs), saturated and unsaturated aldehydes, and ethyl esters are fat-derived flavor volatiles that play an important role in the overall flavor of cheese [30].

FFAs are formed by the oxidation and decarboxylation of fatty acids [31, 32].

In this study, only nonanal was determined as the aldehyde. The amount of nonanal was higher than the values determined by Nogueira et al. [33], Karagül-Yüceer et al.[34] and Çetinkaya and Kaban [35]. The threshold value of aldehydes is very low, and they are compounds formed as a result of amino acid catabolism and lipid oxidation. These compounds turn into alcohols and acids during maturation [1].

Acids are compounds that can be formed through lipolysis, proteolysis, and fermentation of lactose [36, 37]. Free fatty acids have strong sensory properties and are important compounds in the formation of flavor and aroma of many dairy products, especially cheese and fermented milk products [38]. Hexanoic Acid, butanoic acid and acetic acid have a larger share among the acids determined in Ardahan Tel cheese. Studies on the aroma components of different cheese types have also reported that these three acids have an important role in the volatile compound profile [33, 35, 37, 39]. The acetic acid and butanoic acid levels of the samples were higher than the values determined by Hayaloglu and Karabulut [37] in Civil cheese samples and lower than the values determined by Çetinkaya and Kaban [35] in Kars Gravyer cheese. The hexanoic acid levels of the samples were higher than the values determined by Çetinkaya and Kaban [35] and Gün et al [40].

Alcohols are formed by lactose metabolism, reduction of methyl ketones, amino acid metabolism, and the breakdown of unsaturated fatty acid [36]. Ethanol gave the highest level of alcohol in the samples. Similarly, studies on different cheese types have reported higher ethanol ratio among alcohols [33, 35]. Ethanol, 1-Butanol, 3-methyl, 2-heptanol and 1-hexanol values determined in Ardahan Tel cheeses were higher than the values determined in Minas cheese by Nogueira et al. [33] and in Civil cheese samples by Hayaloglu and Karabulut [37] and in Kars Gravyer cheese by Çetinkaya and Kaban [35]. The amount of 2-heptanol was lower than the value determined by Karagül-Yüceer et al [34] in Çanakkale Ezine cheese, and the amount of pentanol was similar to the value determined by Çetinkaya and Kaban [35] in Kars Gravyer cheese.

Esters are formed by esterification of alcohols with short chain carboxylic acids [35]. As can be seen from Table 3, among the esters detected in the samples, ethyl acetate and butyl acetate gave higher levels and were determined in all samples. Aroma active esters are compounds formed as a result of the reaction (esterification) of short or medium chain fatty acids and alcohols [27]. It is reported that most esters detected in cheeses give a fruity or floral taste sensation and their sensory perception thresholds are low [41].

The amount of ethyl acetate determined in the Tel cheese samples was higher than the values determined in Civil cheese by Hayaloglu and Karabulut [37] in Akçakatık cheese by Şimşek and Tuncer [42] and in Coalho cheese by Bezzara et al [39] and butyl acetate amounts were close to the values determined by Çetinkaya and Kaban [35] in Kars Gravyer cheese.

Ketones are mainly formed by the action of fungal or bacterial enzymes as a result of the conversion of triglycerides into free fatty acids by lipase. Ketones can be reduced to alcohols and give a sharp taste to cheeses [36]. The change in the amount of free fatty acids in cheese is also reflected in the methyl ketone composition that occurs [35]. Free fatty acids serve as substrates, especially in the formation of methyl ketones, lactones and esters [35]. 9 compounds were determined in the ketone group, and the highest rate was found in 2-heptanone. 2-heptanone ratios were found to be higher than the ratios determined by Hayaloglu and Karabulut [37] in Civil cheese and by Bezzara et al. [39] in Coalho cheese, but lower than the values determined by Çetinkaya and Kaban [35] and Kavaz et al. [43] .

Hydrocarbons are mostly secondary products formed as a result of the autoxidation of oil [44]. Although these compounds do not directly affect the aroma of cheese, they can act as a precursor compound in the formation of other aroma components and are compounds found in trace amounts in cheeses [44]. The aliphatic hydrocarbons determined in the study are hexane, undecene, octane, decane and dodecene, and aromatic hydrocarbons are toluene, p-xylene, benzene,1-ethyl-3-methyl, benzene,1-ethyl-2-methyl and benzene,1,3,5 trimethyl. The amount of toluene determined in Tel cheeses was higher than the value determined by Kesenkeş and Akbulut [44] in white cheese and by Hayaloglu and Karabulu [37] in Civil cheese. Hexane gave the highest rates in all samples. Hexane levels were higher than the values determined by Hayaloglu and Karabulut [37], Kavaz et al. [43] and Çetinkaya and Kaban [35] in different types of cheese. The amount of octane determined in cheese samples was higher than the values determined by Çetinkaya and Kaban [35] in Kars Gravyer cheese. The difference in hydrocarbon amounts can be affected by the type of cheese types, production method, ripening conditions and period.

Terpenes are volatile compounds of vegetable origin that do not form during the ripening of cheeses and pass into the product through milk as a result of grazing the animal on the pasture [1]. In the research, α-pinene, D-limonene and 3-carene were determined as terpenes. D-limonene showed the highest proportions in 11 samples. D-limonene value in cheese samples were determined to be higher than the values determined by Akpınar et al.

[45] in İzmir Tulum cheese made from cow's milk and by Çetinkaya and Kaban [35] in Kars Gravyer cheese.

Conclusion

- Ardahan Tel cheese is a non-fat cheese variety with a pH value of 5–6. However, the salt content can be up to 10%.
- Lactococci and lactobacilli have an important share in the microbiota of this cheese variety. The number of coliform group bacteria is below the detectable limit. This result is a good indication of the high hygienic quality of this traditional product. It is understood that the salt ratio is an important factor in the inhibition of coliform group bacteria.
- Dry matter content of this cheese type is generally around 50%. The volatile compound profile of this cheese is composed of aldehydes, ketones, alcohols, acids, esters, terpenes, aliphatic hydrocarbons and aromatic hydrocarbons.
- The most Tel here is that aldehydes formed as a result of lipid oxidation are generally at a very low level in this product.
- Only nonanal was identified as aldehyde. Among alcohols, the ethanol level draws attention. In addition to acetic acid, butanoic acid and hexanoic acid are thought to contribute to the aroma of this cheese variety. According to the results obtained, ethyl acetate also contributes significantly to the volatile compound profile.

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Effects of intermittent microwave drying conditions on characteristics and physical properties of beetroots

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Abstract

Introduction. The purpose of this study is to explore the effects of intermittent microwave drying conditions (microwave pulse ratio, microwave power density and slice thickness) on drying characteristics and physical properties of beetroots.

Materials and methods. Drying characteristics and physical properties of beetroots were investigated using intermittent microwave drying at different microwave pulse ratios (1, 2, 3, and 4), microwave power densities (1.0, 1.5, 2.0, and 2.5 W/g) and slice thicknesses (2, 4, 6, and 8 mm). Moisture analyzer and portable water activity meter were used to determine moisture content and water activity of beetroots, respectively. The weighing method was used to assess the rehydration capacity of dried beetroots. In order to evaluate the color quality of beetroots, a colorimeter was used.

Results and discussion. The moisture ratio continuously decreased with the extension of drying time at all drying treatments. Except for microwave power density of 2.5 W/g, all the drying conditions presented a short heating (warm-up) period, an approximately constant rate drying period and a falling rate drying period. Meanwhile, the drying time decreased with increasing microwave power density, while increased significantly with the growth of microwave pulse ratio and slice thickness. There was no significant difference in the final moisture content and water activity of dried beetroots under all drying treatments. The rehydration ratio decreased with the increase of slice thickness (from 2 to 8 mm), microwave power density (from 1.5 to 2.5 W/g), and microwave pulse ratio (from 2 to 4). Compared to fresh beetroots, all the beetroots after intermittent microwave drying had lower *a* and *C* values, and higher *L* values.

Conclusions. Considering drying characteristics and physical properties of beetroots, and energy consumption, the optimal microwave intermittent drying conditions for fresh beetroots are microwave pulse ratio of 2, microwave power density of 2.0 W/g, and slice thickness of 2 mm.

Introduction

As one of the most important and widely grown vegetables, the global production of beetroot (*Beta vulgaris* L.) was about 301 million tons in 2017 with a harvested area of 4.89 million hectares [1]. Beetroots contain a variety of nutritional and bioactive ingredients, for instance, betalains, polyphenols, ascorbic acids, flavonoids, carotenoids, vitamins, minerals, nitrates, and saponins [2]. Recent studies have shown a variety of health benefits for beetroots, such as antioxidative, anti-inflammation, antidiabetic, anticancer, anti-obesity effects, blood pressure and lipid lowering [3]. Due to its good taste and high nutritional value, beetroots are widely consumed and used for manufacturing food coloring agents [4]. Beetroot is prone to spoilage due to its high moisture content, making it perishable.

Drying is one of most widely used methods for preservation of fresh vegetables and fruits, which can prevent microbial spoilage and deterioration reactions and allow their use during off-season [5]. Microwave drying is an efficient drying method, can enhancement of heat and mass transfer, development of internal moisture gradients which increase drying rate as well as improvement of product quality [6]. However, the continuous microwave heating may easily cause rapid heat transfer, the risk of hot spots, product overheating, and undesirable changes in quality [7]. Intermittent microwave drying or microwave intermittent drying was proposed on the basis of conventional microwave drying by considering the existing problems. In intermittent microwave drying, temperature and moisture are redistributed within the product during the microwave off time [8]. Realizing the benefits of intermittent microwave drying, several researchers have explored experimentally drying kinetics and quality of different vegetables and fruits dried by intermittent microwave drying. Zhao et al. [9] investigated the physical changing trend and mechanism of litchi under microwave intermittent drying. Aghilinategh et al. [10] studied the effects of intermittent microwave convective drying parameters on apple color properties. Dai et al. [11] explored the drying characteristics and modeling of apple slices during microwave intermittent drying. There are few studies on intermittent microwave drying of beetroots.

This study proposes a way of improving the drying characteristics and quality indicators of beetroots through the application of intermittent microwave drying.

The objective of the study is to explore the effects of microwave pulse ratio, microwave power density and slice thickness on drying characteristics and physical properties (moisture content, water activity, color, and rehydration ratio) of beetroots.

Materials and methods

Materials

Fresh beetroots (*Beta vulgaris* L.) were purchased from a local market in the city of Xuzhou in Jiangsu Province, China. Before drying, beetroots were stored in a refrigerator at 4 °C. At the beginning of each experiment, whole fresh beetroots were washed by running water. The washed beetroots were peeled and then cut transversely with a stainless steel slicer, chopped into 80-mm diameter slices with different thicknesses.

Design of intermittent microwave drying conditions

To investigate the drying characteristics and physical properties of beetroots, a four-level factorial experimental design with three factors, namely microwave pulse ratio,

microwave power density and slice thickness was constructed. The levels of microwave pulse ratio were 1, 2, 3, and 4, respectively, microwave power density were 1.0, 1.5, 2.0, and 2.5 W/g, respectively, and those of slice thickness were 2, 4, 6, and 8 mm, respectively. The microwave pulse ratio (PR) was calculated by the following equation [12]:

$$PR = \frac{t_{on} + t_{off}}{t_{on}} \quad (1)$$

Where t_{on} is the microwave on-time, and t_{off} shows the microwave off-time. The microwave on–off time employed in this intermittent microwave drying was as following: 3 min on–0 min off (PR = 1), 3 min on–3 min off (PR = 2), 3 min on–6 min off (PR = 3), and 3 min on– 9 min off (PR = 4).

Weighed slices of fresh beetroots (260±2 g total mass), were placed symmetrically on a 30-cm diameter circular fiberglass plate (turntable), which was mounted inside the drying chamber and rotated at 4 rpm to ensure uniform microwave irradiation. A microwave drying system (SAM-255, CEM Corporation, USA) with a maximum output of 650 W at 2450 MHz was used in the experiments. During the drying process, the change in the beetroots' weight was recorded at intervals of 3 min by an electronic balance (CP512, Ohaus Instrument Co. Ltd., China). Drying was carried out until the beetroots presented 0.04 g/g on a dry basis. All drying experiments were repeated five times.

Determination of moisture content and water activity

The moisture content (wet basis) of beetroots was determined by a moisture analyzer (HX204, Mettler Toledo Co. Ltd., Switzerland) at 105 °C. Moisture content (MC) on the dry basis was calculated using the following equation [13]:

$$MC = \frac{M_w}{M_s} \quad (2)$$

where M_w is the water mass (g) and M_s is the mass of sample's dry solids (g). Average initial moisture content of beetroot was 12.02 g water/g dry solids (g/g).

The water activity of beetroots was determined by a portable water activity meter (Aqualab 4TE Duo, Rotronic Co. Ltd., USA) at 25 °C.

Moisture ratio

Moisture ratio (MR) was calculated by using the following expression:

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad (3)$$

where the M_t, M_0, and M_e are moisture content of sample at any time, initial time, and equilibrium, respectively (g/g). For microwave drying, it can be assumed that $M_e = 0$ [14].

Drying time

The time taken to the moisture content of beetroots from the initial level (12.02 g/g) to 0.04 g/g under various intermittent microwave drying conditions was identified as drying

time. Therefore, the drying time of beetroots includes microwave on time and microwave off time.

Drying rate

The drying rate (DR) was calculated according to the following equation [15]:

$$DR = \frac{M_t - M_{t+\Delta t}}{\Delta t} \quad (4)$$

where DR is the drying rate, g/(g·min); $M_{t+\Delta t}$ and M_t are the dry basis moisture content of the sample at t+Δt and t respectively, g/g; Δt is the time difference between two consecutive measurements, min.

Determination of rehydration capacity

The rehydration capacity was performed by dipping 2.0 g dried beetroots into 200 mL of distilled water at 80 ℃ for 15 min. The rehydrated beetroots were taken out, the surface moisture of rehydrated beetroots were absorbed with absorbent papers, and then weighed. The test was performed thrice. Rehydration ratio of dried beetroots was calculated by the following expression [16]:

$$RR = \frac{m_2}{m_1} \quad (5)$$

where RR is the rehydration ratio; m_1 is the mass of dried beetroots, g; m_2 is the mass of beetroots after rehydration, g.

Determination of color parameters

Color of beetroots was measured using a colorimeter (CR-400, Konica Minolta Sensing, Inc., Osaka, Japan). The beetroots dried by different intermittent microwave drying conditions and fresh beetroots were grounded and the measured. The samples were placed in a standard light and the Hunter L (lightness), a (redness), and b (yellowness) values were determined. The L, a, b values were used to calculate total color difference (ΔE), chroma (C) and hue angle (H°) to describe color changes after drying. C changes from 0 (dull) to 60 (vivid) and was calculated by Equation (6) [17].

$$C = \sqrt{a^2 + b^2} \quad (6)$$

The color of food samples generally characterizes by calculating hue angle (H°) value as shown in the Equation (7). Values of H° range from 0° (red), 90° (yellow), 180° (green) to 270° (blue) [18].

$$H° = \tan^{-1}\left(\frac{b}{a}\right) \quad (7)$$

Total color change (ΔE) indicates the magnitude of color change after drying and was evaluated by using the following equation [10].

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \quad (8)$$

where L, a, and b are the values of dried beetroots, L_0, a_0, and b_0 are the values of fresh beetroots. The measurements were done 5 times for each sample.

Statistical analysis

The experimental results were expressed as mean±standard deviation (SD). The responses of the physical analyzes were submitted to analysis of variance (ANOVA), followed by the Duncan's Test ($p < 0.05$) using SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA). Figures were drawn using Origin 2017 (Origin Lab, MA, USA)

Results and discussion

Physical properties of fresh beetroots

The fresh beetroots were analyzed physical properties, which are given in Table 1. The beetroot used is high water content vegetable. The moisture content of fresh beetroots was as high as 92.32±1.37% on a wet basis, and the water activity up to 0.9852±0.0025. Lightness (L), redness (positive a) and yellowness (positive b) of fresh beetroots were 36.83±1.14, 28.78±2.22 and 6.35±1.06, respectively. The $H°$ value of fresh beetroots was 4.53±0.48, indicating a greater tendency to reddish hue.

Table 1

Physical properties of fresh beetroots (before drying)

Attribute	Content
Initial moisture content, %	92.32±1.37
Water activity	0.9852±0.0025
L	36.83±1.14
a	28.78±2.22
b	6.35±1.06
C	29.47±2.39
$H°$	4.53±0.48

Effect of microwave pulse ratio on drying characteristics and physical properties of beetroots

Microwave pulse ratio represents a ratio which is calculated by dividing the sum of the microwave on and off time by the microwave on time [12]. In order to determine the influence of microwave pulse ratio on the drying characteristics and physical properties of beetroots, the beetroots were dried at the slice thickness of 4 mm and microwave power density of 2.0 W/g, and the microwave pulse ratio ranged 1, 2, 3, and 4.

Figure 1 presents the drying curves of beetroots at different microwave pulse ratios. As can be seen, the moisture ratio (MR) decreased as drying process at all microwave pulse ratios, and the shortest drying time was obtained using the lower microwave pulse ratio (PR = 1).

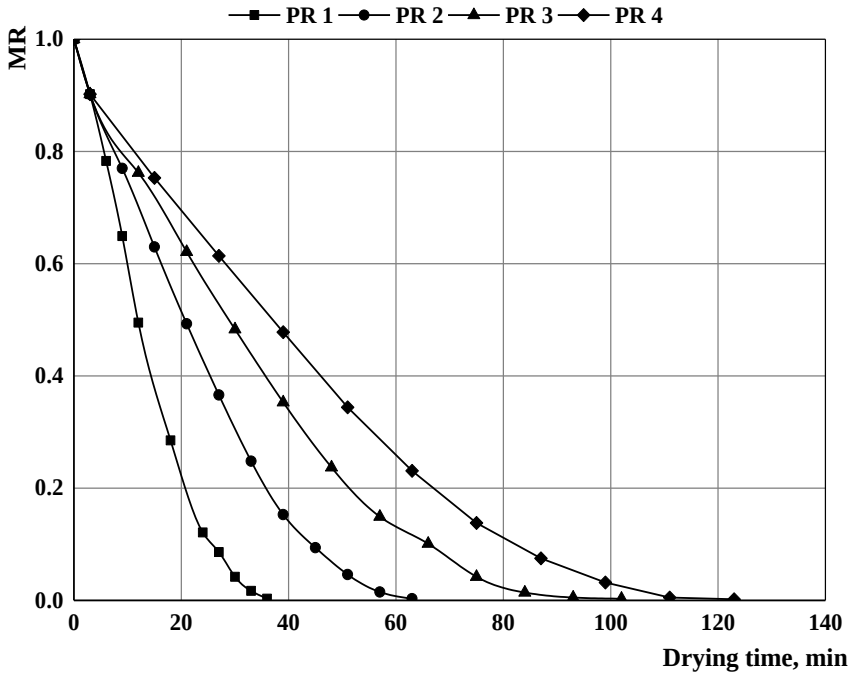

Figure 1. Drying curves of the beetroots at different microwave pulse ratios

The drying rates (*DR*) of the beetroots at different microwave pulse ratios are shown in Figure 2.

It was reported that microwave drying of high initial moisture materials has three periods, a short heating period, a constant drying rate period and a falling drying rate period [19]. For beetroots dried at microwave pulse ratio of 1 (PR = 1), the whole drying process took place in a warm-up period (short heating period) and then showed a falling-rate phase, not existence of a constant drying rate period. When the microwave pulse ratios were 2, 3, and 4, three well-defined drying periods were evident, a short heating period, a constant drying rate, and a falling drying rate period. As microwave pulse ratio increased, the length of the constant drying rate period increased. This phenomenon could be due to the longer microwave off time, which provided longer rest time for better moisture and temperature distribution inside the sample until the following microwave on time [20]. Similar findings are founded in various intermittent microwave drying of grated carrots [21] and cranberries [22].

The moisture content, water activity, drying time and rehydration ratio of beetroots at different microwave pulse ratios can be seen in Table 2.

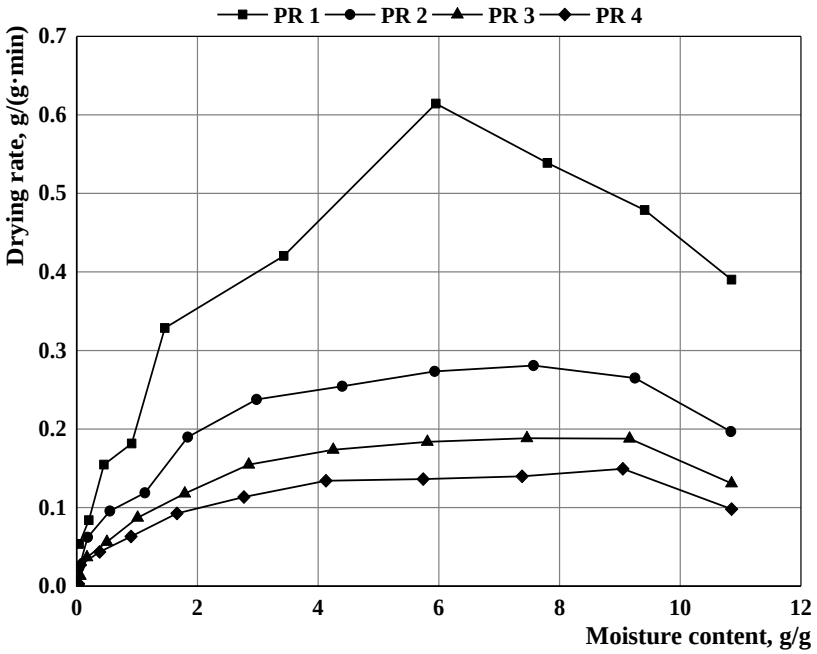

Figure 2. Drying rate variations of beetroot as a function of moisture on a dry basis at different microwave pulse ratios

Table 2

Moisture content, water activity, drying time and rehydration ratio of beetroots at different microwave pulse ratios

Microwave pulse ratio	Moisture content, %	Water activity	Drying time, min	Rehydration ratio
1	3.59±0.62^{a}	0.2954±0.0152^{a}	35.4±1.2^{d}	5.27± 0.16^{ab}
2	3.69±0.48^{a}	0.2988±0.0121^{a}	61.8±2.4^{c}	5.48±0.10^{a}
3	3.65±0.66^{a}	0.2974±0.0176^{a}	96.6±4.4^{b}	5.05±0.10^{bc}
4	3.59±0.49^{a}	0.2946±0.0106^{a}	115.8±5.9^{a}	4.94±0.08^{c}

*Different letters in the same column represent significant differences according to Duncan's Test ($p < 0.05$).

Fresh beetroots had a moisture content of 92.32±1.37%, which were dried to moisture content of less than 4.00%. As shown in Table 2, the final moisture content of beetroots ranged from 3.59±0.62% to 3.69±0.48% on a wet basis, with no significant difference among all the microwave pulse ratios. In addition to reducing the weight and volume of materials, the reduction of moisture also helps increase the stability of dried products, and increases the service life and facilitates the transportation and storage of the product, thereby reducing waste and cost [23]. The water activity (a_w) of dried beetroots was between 0.2946±0.0106 and 0.2988±0.0121 (Table 2), and there was no significant difference among all the

microwave pulse ratios. The reduction of a_w can minimize reactions of deterioration and growth of microorganisms, which contribute to the conservation and extension of the product shelf life [24]. The drying time of beetroots at different microwave pulse ratios from initial moisture content of 12.02 g/g to reach the desired moisture content of 0.04 g/g is shown in Table 2. It can be seen from Table 2 that the drying time increased significantly ($p < 0.05$) with the increase of microwave pulse ratio. The drying time with the microwave pulse ratio of 1 was the shortest (35.4±2.6 min), while the drying time with the microwave pulse ratio of 4 was the longest (115.8±5.9 min). It was found that the whole drying time increased by about 227.1% as the microwave pulse ratio changed from 1 to 4.

Rehydration capacity is a major quality parameter of dried products, which indicates the ability of the product to maintain its original shape and reflects the degree of damage to the cellular during the drying process [25]. The rehydration ratio of beetroots increased with an increase in microwave pulse ratio from 1 to 2 and decreased with a decrease in microwave pulse ratio from 3 to 4. Dried beetroots at microwave pulse ratio of 2 showed the highest rehydration ratio (5.48±0.10) as compared to other microwave pulse ratios. At microwave pulse ratio values of 1 to 2, the beetroots exhibited a high degree of drying and strong ability to absorb water. Increasing microwave pulse ratio prolonged the off time for drying beetroots. Less porous structures were formed when the microwave was turned off, resulted in a reduced rehydration ratio [26]. Similar observation was also reported in microwave vacuum drying of tilapia fillets [27].

The results of color changes in beetroots for all microwave pulse ratios are given in Table 3.

Table 3

Color parameters of dried beetroots as affected by microwave pulse ratios

Color	Microwave pulse ratio			
	1	2	3	4
L	48.96±0.85^{a}	48.29±0.98^{ab}	47.72±0.89^{ab}	46.91±0.78^{b}
a	26.03 ±0.38^{a}	24.97±0.79^{b}	22.54±0.42^{c}	20.98±0.15^{d}
b	5.27±0.23^{b}	6.68±0.35^{a}	5.36±0.25^{b}	5.51±0.05^{b}
C	26.55±0.42^{a}	25.85±0.84^{a}	23.17±0.47^{b}	21.69±0.17^{c}
H°	4.88±0.14^{a}	3.58±0.11^{c}	4.13±0.12^{b}	3.72±0.05^{c}
Δ*E*	12.49±0.91^{a}	12.10±1.12^{a}	12.60±0.87^{a}	12.80±0.9^{a}

*Data in the same row with different letters are significantly different according to Duncan's Test ($p < 0.05$).

Obviously, it can be seen that the *L* values after drying were significantly higher than that of fresh beetroots. The lowest *L* value obtained from the beetroots dried by microwave pulse ratio of 4, which had darker color than other microwave pulse ratios. Compared to fresh beetroots, *a* (redness) values significantly decreased after drying by different microwave pulse ratios. It can be seen that *a* (redness) value decreased with the increasing of microwave pulse ratio. The *a* values of dried beetroots were significantly affected by microwave pulse ratio ($p < 0.05$). The decrease of *a* value might be due to the degradation of pigments such as betacyanins. The highest *b* value (6.68±0.35) was obtained from beetroots dried at microwave pulse ratio of 2, which was significant higher than that of other microwave pulse ratios ($p < 0.05$).

The *C* values of beetroots dried under different microwave pulse ratios were significantly lower than that of fresh beetroots (see Table 1 and Table 3). Dried beetroots at microwave pulse ratio of 1 showed the highest *C* value (26.55±0.42) as compared to other microwave pulse ratios. The *C* values of dried beetroots at microwave pulse ratio of 1 and 2 were significantly higher than ($p < 0.05$) that of beetroots at microwave pulse ratio of 3 and 4. The lowest *H*° value (3.58±0.11) was obtained from beetroots dried at microwave pulse ratio of 2, while the highest value (4.88±0.14) was obtained from beetroots dried at microwave pulse ratio of 1. It has been explained that the reduction in *H*° value is an expression of more darkening color [28]. As can be seen from Table 3, microwave pulse ratio has no significant effect on total color change (ΔE) ($p > 0.05$).

As a result, the beetroots dried at microwave pulse ratio of 1 showed a greater tendency towards bright, red, greater color saturation and a more yellowish hue compared to the beetroots dried at other microwave pulse ratios.

Effect of microwave power density on drying characteristics and physical properties of beetroots

The effect of microwave power density on the drying characteristics and physical properties of beetroots was investigated at the microwave pulse ratio of 2 and slice thickness of 4 mm. Four different levels of the microwave power, namely, 260, 390, 520 and 650 W, were investigated. Based on the initial mass of 260 g, of the fresh beetroot slices, these values correspond to microwave power density of 1.0, 1.5, 2.0, and 2.5 W/g, respectively.

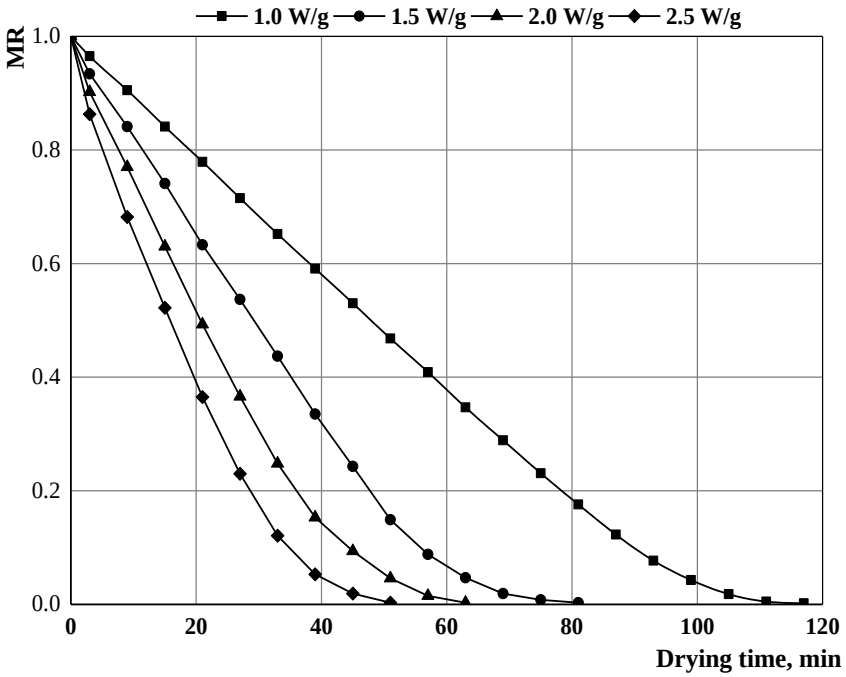

Figure 3. Drying curves of the beetroots at different microwave power densities

The drying curves of beetroots at different microwave power densities are shown in Figure 3. It can be seen that the moisture ratio gradually decreased with the drying process under all the microwave power densities. It is obvious that the higher the power, the less time necessary to dry the beetroots. Higher microwave power density provides more energy for sublimation, thus accelerating the drying process. It reveals that drying carried out at higher microwave power density give shorter drying duration. Similar results have been reported in microwave drying of apple slices [11] and bitter melon [29].

Figure 4 shows the drying rate curves of beetroots at different microwave power densities.

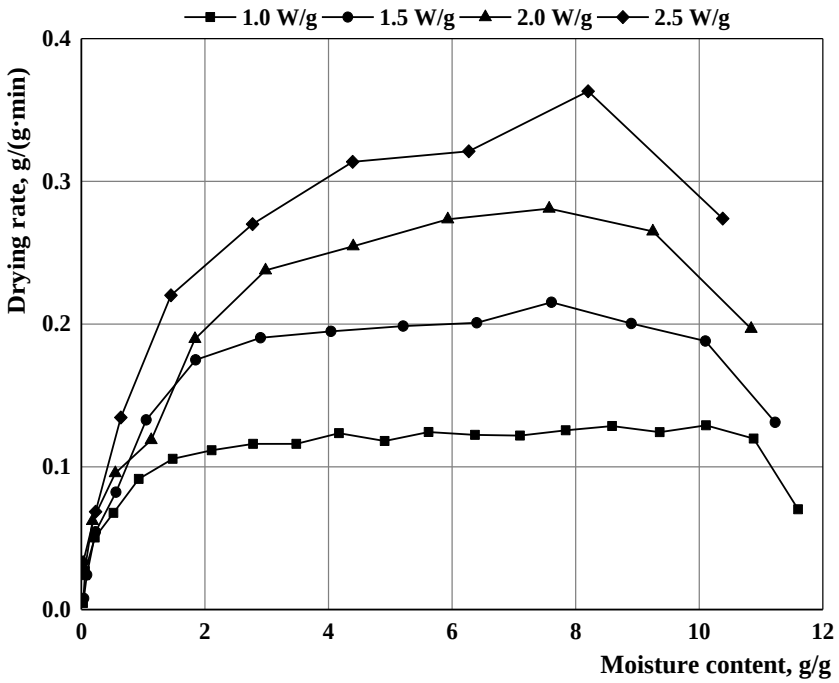

Figure 4. Drying rate variations of beetroot as a function of moisture on a dry basis at different microwave power densities

The drying rate increased with the increase of microwave power density. The reason is that the weaker microwave radiation cannot completely penetrate the material, so the material dehydration starts from the adjacent part of epidermis, and then the dehydrated part forms a relatively tight porous network structure, which hindered the migration and removal of moisture. While the stronger microwave radiation can penetrate the material more effectively so that the material can quickly remove moisture from the inside to the outside [30].

Results showed that intermittent microwave drying at 2.5 W/g occurred mainly in the falling rate period, whereas drying at lower powers resulted in relatively longer constant rate periods. It is clearly seen that the drying rate was an increasing trend at the early stage of the drying process (Figure 4). In the initial stage of drying, the inside and outside of the material were heated at the same time, the temperature rose rapidly, and the moisture inside the

material continuously migrated to the outer surface; meanwhile the outer surface was easier to dissipate due to evaporation and diffusion, causing a temperature gradient difference between the inside and the outside of the material, and the direction of the temperature gradient was the same as the direction of water migration, so the drying rate increased [31]. At 1.0 and 1.5 W/g, a relatively longer constant drying rate period was observed. In addition, the drying rate was in a decreasing trend (falling rate period) at the final stage of the drying process. After a short heating process during the early stage of drying, the drying rate at 2.5 W/g increased to a maximum and then decreased without a distinct constant drying rate period. On the contrary, a relatively long constant rate period was visible at lower specific powers (1.0 and 1.5 W/g). In the middle of drying period, microwave heating is completely used for the vaporization of moisture, and the drying rate is relatively stable. At this time, the rate of water loss on the surface of the beetroots is equal to the rate of outward migration of internal moisture, so there is a constant rate period. In the later stage of drying, the free water in the beetroot was basically removed. At this time, the combined water is mainly contained in the beetroots, and the combined water is more difficult to remove, and the absorbed microwave energy is reduced, so the drying rate gradually decreases and enters the reduced-speed drying stage.

Table 4 shows the moisture content, water activity, drying time and rehydration ratio of beetroots dried at different microwave power densities.

Table 4

Moisture content, water activity, drying time and rehydration ratio of beetroots at different microwave power densities

Microwave power density, W/g	Moisture content, %	Water activity	Drying time, min	Rehydration ratio
1.0	3.60 ± 0.42^{a}	0.2947 ± 0.0090^{a}	117.0 ± 3.8^{a}	5.57 ± 0.16^{ab}
1.5	3.68 ± 0.44^{a}	0.2962 ± 0.0115^{a}	77.4 ± 2.9^{b}	5.82 ± 0.09^{a}
2.0	3.69 ± 0.48^{a}	0.2988 ± 0.0121^{a}	61.8 ± 2.4^{c}	5.48 ± 0.10^{b}
2.5	3.61 ± 0.55^{a}	0.2951 ± 0.0148^{a}	53.4 ± 2.9^{d}	5.11 ± 0.09^{c}

*Different letters in the same column represent significant differences according to Duncan's Test ($p < 0.05$).

The final moisture content of dried beetroots ranged from 3.60±0.42% to 3.69±0.48% on wet basis, meanwhile, the final water activity ranged from 0.2947±0.0090 to 0.2988±0.0121. There were no significant difference in the final moisture content and water activity of dried beetroots under different microwave power densities ($p > 0.05$). It can be seen from Table 4 that the drying time decreased significantly with the increase of microwave power densities ($p < 0.05$). The time to dry the beetroots reduced around 47.2% when microwave power density increased double (from 1.0 to 2.0 W/g), and when the microwave power density was 2.5 W/g, the drying time was only 45.6% of that the microwave power density of 1.0 W/g. The lowest drying time (53.4±2.9) of beetroots was found at microwave power density of 2.5 W/g.

It was observed that rehydration ratio decreased as microwave power density increased from 1.5 to 2.5 W/g. The lowest rehydration ratio (5.11±0.09) occurred when the microwave

power was 2.5 W/g. As we known, the lower rehydration ratio, the more severe damage to the cell structure of the sample.

The color changes of dried beetroots at different microwave power densities are shown in Table 5.

Table 5

Color parameters of dried beetroots as affected by microwave power densities

Color	Microwave power density, W/g			
	1.0	1.5	2.0	2.5
L	48.60±1.20^{ab}	49.99±1.24^{a}	48.29±0.98^{bc}	46.75 ±0.85^{c}
a	23.67±0.50^{b}	23.30±0.67^{b}	24.97±0.79^{a}	23.72 ±1.13^{b}
b	6.76±0.33^{a}	6.39±0.41^{a}	6.68±0.35^{a}	5.52±0.66^{b}
C	24.61±0.57^{ab}	24.16±0.75^{b}	25.85±0.84^{a}	24.35 ±1.25^{b}
H°	3.41±0.11^{b}	3.56±0.13^{b}	3.58±0.11^{b}	4.26±0.31^{a}
Δ*E*	12.85±1.25^{ab}	14.26±1.39^{a}	12.10±1.12^{b}	11.22±1.17^{b}

*Data in the same row with different letters are significantly different according to Duncan's Test ($p < 0.05$).

Compared to fresh beetroots (Table 1), the *L* values of dried beetroots increased significantly. The lowest *L* value (46.75±0.85) of dried beetroots was obtained at microwave power density of 2.5 W/g, while the highest value (49.99±1.24) was obtained at microwave power density of 1.5 W/g. It can be seen from Table 1 and Table 5, the *a* values of beetroots dried at all microwave power densities were lower than that of fresh beetroots. The highest *a* value (24.97±0.79) was obtained from beetroots dried at microwave power density of 2.0 W/g, which was significantly different from other microwave power densities ($p < 0.05$). The lowest *b* value (5.52±0.66) was obtained from the beetroots dried by microwave power density of 2.5 W/g, which was significantly different from other microwave power densities ($p < 0.05$).

It also can be seen from Table 1 and Table 5, the *C* values of beetroots dried at different power densities were obviously lower than that of fresh beetroots. The highest *C* value (25.85±0.84) in the dried beetroots produced using the microwave power density of 2.0 W/g. It was observed that microwave power density of 1.0, 1.5 and 2.5 W/g had no significant effect on *C* values ($p > 0.05$). It can be seen from Table 5 that the highest *H*° value (4.26±0.31) was obtained from the beetroots dried at microwave power density of 2.5 W/g. When the microwave power densities were 1.0, 1.5, and 2.0 W/g, the effect on the *H*° value was not significant ($p > 0.05$). The highest Δ*E* value (14.26±1.39) was obtained from beetroots dried at microwave power density of 1.5 W/g, while the lowest value (11.22±1.17) was obtained from beetroots dried at microwave power density of 2.5 W/g.

As a result, the beetroots dried at microwave power density of 2.0 W/g showed a greater tendency towards red and greater color saturation compared to the beetroots dried at other microwave power densities.

Effect of slice thickness on drying characteristics and physical properties of beetroots

To explore the effect of slice thickness on drying characteristics and physical properties of beetroots, the experiments were carried at microwave pulse ratio of 2, and microwave power density of 2.0 W/g.

The drying curves of the beetroots at different slice thicknesses are presented in Figure 5. The MR decreased as drying process at all slice thicknesses. As the slice thickness increased, the drying time required for the beetroots to reach final moisture content increased, and the shortest drying time was obtained at the thinnest slice thickness (2 mm). It reveals that drying carried out at thinner slice thickness gave shorter drying duration.

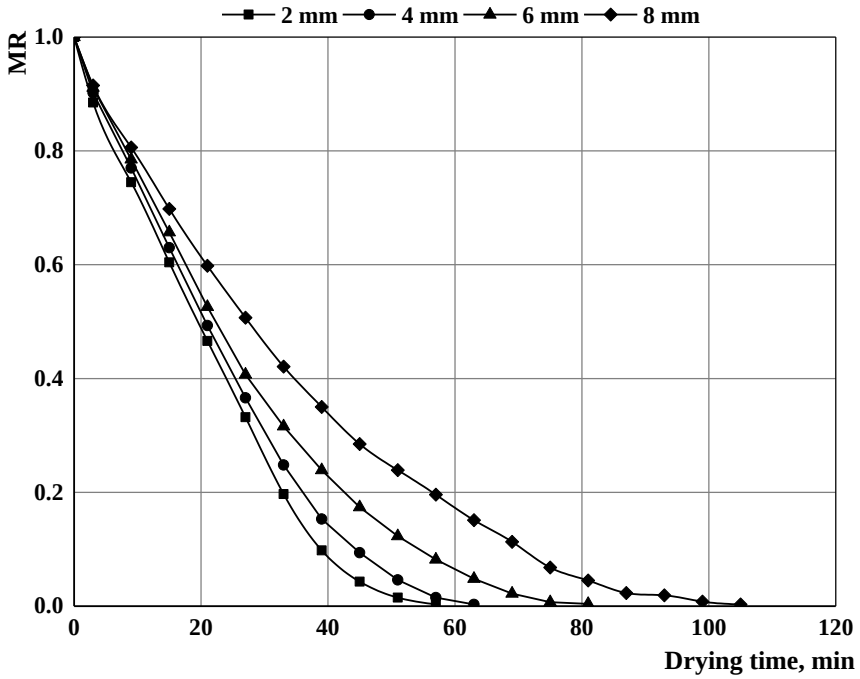

Figure 5. Drying curves of the beetroots at different slice thicknesses

The drying rates (DR) of the beetroots at different slice thicknesses are shown in Figure 6. The DR of beetroots reduced with the increase of slice thickness. This may be attributed to the reason that thicker samples would lead to a longer migration path for the water molecules transferred from inner to external [11]. It is easy to see from Figure 6 that the DR of beetroots was higher at the beginning of drying, when the moisture content of the beetroots was higher. An increase in DR was observed in the initial phase for all slice thicknesses. As can be seen in Figure 6, the constant drying rate time was very short. The DR was gradually reduced until the end of drying, which is due to the reduction of the moisture available for removal and due to the stiffening of the product [24]. It was observed that thinner slice thicknesses resulted in higher DR. The same fact was observed by Dai et al. [11] on microwave intermittent drying of apple slices.

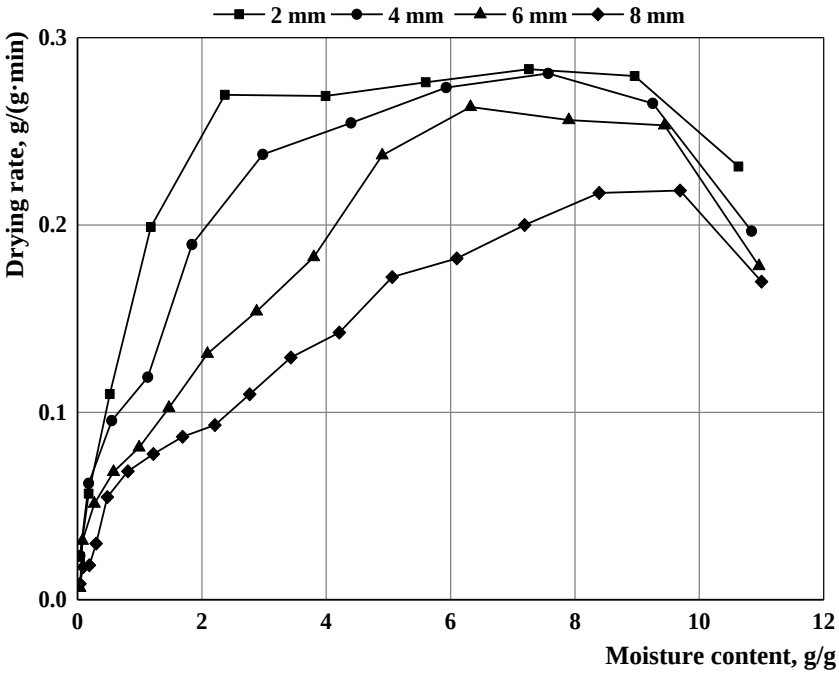

Figure 6. Drying rate variations of beetroot as a function of moisture on a dry basis at different slice thicknesses

Moisture content, water activity, drying time and rehydration ratio of beetroots at different slice thicknesses are presented in Table 6.

Table 6

Moisture content, water activity, drying time and rehydration ratio of beetroots at different slice thicknesses

Slice thickness, mm	Moisture content, %	Water activity	Drying time, min	Rehydration ratio
2	3.67±0.66[a]	0.2977±0.0187[a]	54.6±2.9[d]	6.11±0.14[a]
4	3.69±0.48[a]	0.2988±0.0121[a]	61.8±2.4[c]	5.48±0.10[b]
6	3.62±0.60[a]	0.2957±0.0145[a]	78.6±2.9[b]	4.45±0.13[c]
8	3.61±0.46[a]	0.2961±0.0108[a]	102.6±4.8[a]	3.85±0.05[d]

*Different letters in the same column represent significant differences according to Duncan's Test ($p < 0.05$).

The final moisture content of dried beetroots ranged from 3.61±0.46% to 3.69±0.48% on a wet basis, with no significant difference among all the slice thicknesses. There was no significant difference in the water activity of dried beetroots obtained at all slice thicknesses, and the final water activity was between 0.2957±0.0145 and 0.2988±0.0121. It can be seen

from Table 6 that slice thickness had a significant effect on drying time of beetroots. The drying time of beetroots increased significantly with the increase of slice thickness ($p < 0.05$). The time to dry the beetroots increased around 87.9 % when slice thickness increased quadruple (from 2 to 8 mm). In other words, the drying time of beetroot slices with a thickness of 2 mm was only 53.2% of that of beetroot slices with a thickness of 8 mm.

It was observed that the rehydration ratio was significantly influenced ($p < 0.05$) by the slice thickness (Table 6), in which the higher slice thickness resulted in lower rehydration ratio. The highest rehydration ratio (6.11±0.14) was obtained from beetroots with a slice thickness of 2 mm, while the lowest value (3.85±0.05) was obtained from beetroots with a slice thickness of 8 mm. The rehydration ratio of beetroot slices with a thickness of 8 mm was only 63% that of beetroot slices with a thickness of 2 mm.

The color parameters of dried beetroots at different slice thicknesses are shown in Table 7.

Table 7

Color parameters of dried beetroots as affected by slice thicknesses

Color	Slice thickness, mm			
	2	4	6	8
L	50.46±0.61^{a}	48.29±0.98^{b}	49.72±0.53^{ab}	48.84±1.49^{b}
a	26.47±0.23^{a}	24.97±0.79^{b}	22.32±0.56^{c}	21.99±0.61^{c}
b	6.44±0.13^{b}	6.68±0.35^{b}	8.72±0.41^{a}	8.35±0.43^{a}
C	27.24±0.26^{a}	25.85±0.84^{b}	23.96±0.67^{c}	23.52±0.71^{c}
H°	4.03±0.06^{a}	3.58±0.11^{b}	2.43±0.07^{c}	2.51±0.09^{c}
Δ*E*	13.83±0.62^{a}	12.10±1.12^{b}	14.63±0.55^{a}	13.98±1.34^{a}

*Data in the same row with different letters are significantly different according to Duncan's Test ($p < 0.05$).

The *L* values for all slice thicknesses were in the range of 48.29±0.98 to 50.46±0.61, which were higher than that of fresh beetroots (see Table 1). The maximum *L* value appeared in beetroots with a thickness of 2 mm. It was observed that increasing slice thicknesses decreased *a* value. The decrease in values of *a* was caused by the degradation of pigments such as betacyanins.

The lowest *a* value (21.99±0.61) of dried beetroots was obtained at 8 mm, compared with dried beetroots of other slice thicknesses. The *b* values of dried beetroots with different thicknesses were higher than that of fresh beetroots. The largest *b* value (8.72±0.41) occurred when thickness of the beetroots was 6 mm.

It has been reported that *C* value is a good illustration of the amount of color, can distinguishing vivid and dull color [32]. Compared to fresh samples, the *C* values of dried beetroots at different slice thicknesses were significantly reduced. It can be seen from Table 7 that the increase in slice thickness led to a decrease in *C* value. The lower *C* value of dried beetroots at 8 mm indicated less saturation and a duller appearance compared with dried beetroots in other slice thicknesses. The *H*° values of dried beetroots showed a significant decrease as the slice thickness increased from 2 to 6 mm, and lower than that of fresh beetroots. The *H*° value of dried beetroots with a thickness of 6 mm was the lowest (2.43±0.07). The highest Δ*E* value (14.63±0.55) was obtained from beetroots dried at slice thickness of 6 mm, while the lowest value (12.10±1.12) was obtained from beetroots dried at slice thickness of 4 mm.

As a result, the dried beetroots with thickness of 2 mm showed a greater tendency towards bright, red, greater color saturation and a more yellowish hue compared to the dried beetroots of other slice thicknesses.

Conclusion

- The effects of microwave pulse ratio, microwave power density and slice thickness were significant on the drying rates, drying time, rehydration capacities and color quality;
- The moisture ratio decreased as drying process at all drying treatments;
- The short heating (warm-up) periods, approximately constant rate drying periods and falling rate drying periods were found in all the drying rate curves, except for the microwave power density of 2.5 W/g;
- The drying time decreased with increasing microwave power density, while increased significantly with the growth of microwave pulse ratio and slice thickness;
- There was no significant difference in the final moisture content and water activity of dried beetroots under all the microwave drying conditions;
- The rehydration ratio decreased with the increase of slice thickness (from 2 to 8 mm), microwave power density (from 1.5 to 2.5 W/g), and microwave pulse ratio (from 2 to 4);
- All the beetroots after intermittent microwave drying had lower values of *a* and *C*, and higher values of *L* than fresh beetroots;
- Considering drying characteristics and physical properties of beetroots, and energy consumption, fresh beetroot slices with 2 mm dried at microwave power density of 2.0 W/g and microwave pulse ratio of 2 were proposed as the most economic and favorable drying conditions.

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Study of combination of pumpkin seed flour and turkey meat in hams

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Abstract

Introduction. Studies have been conducted to determine the effect of combination of pumpkin seed flour and turkey meat in hams.

Materials and methods. The technology of hams with the use of mathematical modulation and addition to the composition of pumpkin seed flour and turkey meat was studies. Determination of amino acid composition was conducted in accordance with the method of ion exchange chromatography

Results and discussion. The share of muscle tissue in turkey carcasses of the 1st and 2nd grades is within 44–47% and is dominant, the skin content with subcutaneous fat is 13–22%.

Determined that the protein content of oilseeds is indistinguishable from meat raw materials, and they can be considered as a good source of vegetable protein (19.4–34.2%).

Analysis of the amino acid composition of oilseeds proteins showed that they containe all essential amino acids, but there are minor differences in their quantitative content. In oilseeds, the predominant amino acid is leucine for sesame seeds, leucine and valine for sunflower seeds, phenylaline for pumpkin seeds.

Three experimental recipes for restructured ham were developed with the replacement of turkey meat with turkey skin in the amount of 10% and pumpkin seed flour in the amount of 5, 10, 15% hydrated in a ratio of 1:2.

Physico-chemical studies have shown that ham made with the use of turkey skin and pumpkin seed flour have slightly higher protein content and more balanced ratio of protein and fat in the recipe 1:1, according to adequate nutrition,

Conclusions. The high quality of three formulations developed and tested for the production of restructured ham, in which 10% of turkey skin and 5–15% of pumpkin seed flour are combined, has been established.

Introduction

Turkey meat is one of the most valuable types of meat, which is the most important source of complete animal protein, lipids with high levels of polyunsaturated fatty acids [6]. It has high dietary properties and taste qualities [7].

Food with turkey meat has high nutritional value, which means the ability to meet the body needs in proteins, lipids, minerals and vitamins [8]. Unlike pork and beef, turkey meat has high content of complete proteins because it has relatively little connective tissue, it is less coarse, hence fewer incomplete proteins (collagen and elastin) and is more easily exposed to hydrolysis when heat treated. Low fat content localized in the inner cavity of the carcass, intestines, stomach and subcutaneous layer reduces the likelihood of separation of fat in the production of ready-to-eat turkey meat products. Poultry fat tissue contains a large amount of polyunsaturated fatty acids [1, 2].

The muscle tissues of meat contain extractive substances and turkey chest muscles that are involved in the formation of taste and belong to strong activators of the secretion of gastric glands are especially rich of them. Turkey meat contains phosphorus in as big quantities as fish. In addition, turkey meat contains B and PP vitamins, the lack of which causes nervous and mental disorders, skin changes (ulcers, the effect of "orange" skin), leads to lower intelligence [2, 4]

All these factors allow the use of turkey meat for the development of baby food, dietary, therapeutic food and food for functional nutrition of people. High biological value and dietary qualities of turkey meat products allow them to successfully compete with similar products containing pork and beef.

The possibility of combining turkey and pumpkin seeds in meat products requires research.

The purpose of research is to investigate the quality of meat products in which turkey and pumpkin seeds are added.

Materials and methods

Flour preparation.

Preparation of the flour of grains is to wash the grains with running water, soaking the grains in a water reservoir at a temperature of 18±2 °C for 8 hours, re-washing, sprouting grains in a reservoir without water at a temperature of 17±2°C for 3 days to the length of the 1 cm steer, drying the raw material to a moisture content of 16% and chopping up to a particle size of 0.2 mm – 0.4 mm. The size of the particles of the flour is determined by sifting it through a sieve with a passage of 0.2 mm to 0.4 mm grating openings [3].

Determination of amino acid composition

Determination of amino acid composition was conducted in accordance with the method of ion exchange chromatography [4]. Quality and quantitative determination of components consisted in dividing of them into separate components after the hydrolysis of proteins and determination of their quantitative estimation with the help of automatic analyzer of amino acids as T-339, on polystyrene sulfonate ion exchange resins of "Ostion LJ ANB" in Li-citrate buffer one column mode. The elutions of amino acids from a column conduct in turn by Li- by citrate buffers from pH 2,75±0,01; pH 2,95±0,01; pH 3,2±0,02; pH 3,8±0,02; pH

5,0±0,2. Amino acids rectifying with the help of solution of ninhydrin on a running photometer at a length of waves by 560 nm. The results of detection was registered oneself by a variplotter on a paper in form the peaks of absorption of light of ninhydrin-positive substances in an eluate, that in number in direct ratio concentrations of this substance in solution. Correlation of solution of ninhydrin reagent and eluents is 1 to 2; temperature of thermostatic T1=38,5 °C; T= 65 °C. The prototype was diluted in Li-citrate buffer by pH 2,2±0,02 and inflicted on a ion exchange column with the help of metering device. The quantitative estimation of chromatograms of pre-production model settles accounts in relation to standard mixture of amino acids of firm VioRaD. The amount of milligrams of every amino acid of Ai in the investigated solution calculates on a formula:

$$Ai = \frac{M_i \cdot S_i}{S_i^3}$$

where Ai is mass part of and-th amino acid, mg/ 100 g of protein; Mi is molecular mass of i-th amino acid; Si – is area of peak of and the amino acid on an aminogram from the investigated solution; is an area of peak of and amino acid on an aminogram from solution of standard mixture of amino acids, that accords to one micromole.

Amino acid SCORE is expected according to the certificate scale of THEO/WHO [12].

Moisture content determining

The moisture content was determined using the SuperPoint grain moisture meter, which is used for rapid analysis of grain moisture in laboratory and field conditions [13]. To measure the grain humidity, the appliance is switched on, the name of the scale of the corresponding measuring crop or product is selected on the LCD screen, the necessary sample is selected, which falls into the device, the pressure cover of the pressurizes to the level until the pressure indicator is set to the level with the upper surface of the lid. After tightening the button "TEST" is pressed and after 10 seconds the result of the measurements of humidity in% is received. Measurement is carried out with an accuracy of 0.5% with a range of humidity measurement from 8 to 45%.

Results and discussion

Study of the composition of the turkey

The chemical composition of turkey meat depends on the type, age and category of feeding (Table 1) [3, 5].

By type and age, we distinguish meat of young poultry (cockerel) and adult poultry (turkey hen, turkey male).

Carcasses of young poultry have soft (cartilaginous) keel, soft beak, the lower part of which is easily bent, delicate elastic skin. The carcasses of cockerels have smooth skin on legs and underdeveloped spurs in the form of bumps. The carcasses of adult poultry have hard keel and keratinized beak. Turkey hen carcasses have rough skin on legs and male turkey carcasses have legs with hard spurs. Depending on the feeding and quality of post-slaughter processing the turkeys are divided into two categories of feeding – 1 and 2.

The grade of market quality (finish) is determined by the development of muscle tissue and keel bone (keel), amount of subcutaneous fat and the quality of skin treatment.

Table 1

Chemical composition of turkey meat depending on the category of market quality (finish)

Indicator	Turkey meat	
	1st grade	2nd grade
Chemical composition, g in 100 g of product:		
Protein	19.5	21.6
Fat	22.0	12.0
Carbohydrates	–	0.8
Ash	0.9	1.1
Vitamins, in 100 g of product:		
A, mg	0.01	0.01
ß-carotene, mg	Traces	Traces
E, mg	0.34	–
C, mg	–	–
B_6, mg	0.33	0.33
B_{12}, mg	–	–
Biotin, micrograms	–	–
Niacin, mg	7.8	8.0
Pantothenic acid, mg	0.65	–
Riboflavin, mg	0.22	0.19
Thiamine, mg	0.05	0.07
Folacin, mg	9.60	9.40
Choline, mg	139	136
Energy value, kcal	276	197

Carcasses of 1st grade should have the following indicators:

- Muscle tissue is well developed;
- The shape of turkey breast is rounded. The keel bone is slightly protruded;
- Subcutaneous fat on turkey carcasses is on the breast and in the abdomen as well as a strip on the back;
- The quality of post-slaughter treatment of carcass must meet the following requirements: should be bloodless, with clean skin without feather, fluff, pins and hair-like feather, wax, scratches, breaks, stains, bruises and remnants of the intestine.

Eviscerated carcasses have oral cavity and beak cleaned from feed and blood, legs cleaned from dirt and spurs. Single feather pins and light rawness is allowed, no more than two skin cuts 1 cm long each.

Carcasses of the 2nd grade must meet the following requirements:

- Muscle tissue is developed satisfactorily. The keel bone can stand out, breast muscles with keel bone make an angle without fold on its sides;
- Subcutaneous fat is insignificant: carcasses of cockerels and turkey hens have it in the lower back and abdomen;
- With quite satisfactory developed muscle tissue fatty subcutaneous fat may not exist;
- The skin of the 2th grade carcasses may have a small number of feather pins and rawness, no more than three skin cuts up to 2 cm long each.

Poultry carcasses that meet the finish requirements of the 1st grade, and the quality of processing – 2 grade, belong to the 2nd grade.

In turkey meat, the ratio of protein and fat is close to optimal. However, turkey meat of grade 2 contains more protein and water but less fat than poultry meat grade 1. The highest protein content and the least fat is in breast muscle [5, 7].

White turkey meat (breast muscles) differs from red (femoral muscles) with a lower lipid content, connective tissue and hemo-containing proteins.

Turkey meat compared to all other types of poultry meat is more rich in B vitamins and has the lowest cholesterol content.

The connective tissue of poultry meat has less strength than beef and pork, so it is much faster to hydrolysis during heat treatment. Given the high live weight of turkey and meat-making qualities of carcasses, deep processing and sale of dressed turkey carcasses in in accordance with gastronomic purpose, economic feasibility, habits and requests of consumers is carried out.

Table 2 shows data of amino acid composition of turkey meat proteins [6].

Table 2

Amino acid composition of turkey meat proteins

Indicator	Turkey meat	
	Grade 1	Grade 2
Protein, %	19.5	21.6
Amino acid composition, g in 100 g protein		
Essential amino acids:	39.10	39.55
Valine	4.77	4.71
Isoleucine	4.94	4.76
Leucine	8.14	8.42
Lysine	8.39	8.94
Methionine	2.55	2.30
Treonine	4.49	4.45
Tryptophane	1.69	1.64
Phenylalynine	4.12	3.94
Nonessential amino acids:	60.69	60.54
Alanine	6.25	6.12
Arginine	5.99	6.45
asparagine acid	10.30	9.75
Hystidine	2.77	2.02
Glycine	5.83	6.08
glutamic acid	16.82	17.00
Oxyproline	0.93	1.0
Proline	4.26	4.21
Serine	3.77	3.97
Tyrosine	3.16	3.29
Cystine	0.62	0.67
Total amino acids	99.76	99.80
Limiting amino acid, skor, %	No	No

Table 2 shows how high is the level of essential amino acids in turkey meat proteins. Food and biological value is determined by the significant content of essential amino acids, their optimal ratio, as well as good digestibility of meat by digestive tract ferments. Poultry meat proteins, particularly turkey meat, have no amino acids limiting the biological value of these proteins.

Based on this, it should be noted that poultry meat is the most important source of complete animal protein. Food proteins serve as building material for muscle tissue, ferments, hormones [8].

Lipids play important role in assessing the nutritional value of products. Lipids of poultry meat are carriers of energy, their biological value is determined by the content of polyunsaturated (essencial) fatty acids and fat-soluble vitamins. Fats provide good absorption of fat-soluble vitamins in intestine. They play an important role in the formation of meat taste.

Polyunsaturated fatty acids are not synthesized by human body in the required amounts. Fats with higher levels of unsaturated fatty acids contribute more to the absorption of proteic nitrogen. Turkey meat is a source of essential fatty acids, which are part of lipoprotein complex of human body cell membranes, so it is very important to ensure their supply in the required amount.

Poultry fats have melting point below 40 °C, which causes good emulsification in the digestive tract and absorption. Turkey lipids contain high levels of unsaturated fatty acids and especially precious polyunsaturated fatty acids – linoleic, linolenoic and arachidonic (Table 3).

One of the fractions that has the biggest share in the lipids of the edible part of turkey is represented by triglycerides [9].

When considering the fractional composition, the proportion of phospholipids is several times less than triglycerides, however, polyunsaturated fatty acids are found in phospholipids in greater quantities than in triglycerides.

The content of unsaturated fatty acids such as linoleic, linolenoic and arachidonic in turkey meat is almost 2 times bigger than saturated the same trend persists in relation to polyunsaturated essential fatty acids.

Different tissues of turkey meat are classified according to their industrial significance and distinguish between muscle, fat, connective, cartilage bone and blood. The main component of poultry meat is undoubtedly muscle tissue.

The share of muscle tissue in turkey carcasses of the 1st and 2nd grades is within 44–47% and is dominant, the skin content with subcutaneous fat is 13–22% [10].

Poultry meat, particularly turkey, unlike meat of other farm animals, has varying degrees of muscle coloring: from clear pink (white meat) to dark red (red meat) depending on the content in pigment muscles. Red muscles contain less protein, more fat, cholesterol, phosphatids, ascorbic acid; in white muscles there's more carnosin, glycogen, adenosinetriphosphate. Myoglobin content in white muscles is 0.05–0.08%, in red muscles several times more.

Turkey meat has the ability to take the taste of any other meat when used together. This feature of turkey meat is quite successfully used by many manufacturers of sausages, smoked meats, semi-finished products around the world [22].

Table 3

Fractional and fatty acid composition of lipids in turkey meat

Fractional and fatty acid composition of lipids, g in 100 g of meat	Turkey meat	
	Grade 1	Grade 2
Lipids (amount)	**22.00**	**12.00**
Triglycerides	16.06	8.40
Phospholipids	4.40	3.00
Cholesterol	0.21	0.13
Fatty acids (amount)	18.35	9.12
Saturated	**5.82**	**2.91**
including:		
C12:0 (lauric)	0.02	0.01
C14:0 (myristic)	0.23	0.11
C 3:0 p.m. (pentadecadionic)	0.03	0.01
C 4:0 p.m. (palmitic)	4.10	2.06
C 5:0 p.m. (margaric)	0.07	0.03
C 6:0 p.m. (stearic)	1.35	0.67
C20:0 (arachidic)	0.02	0.02
Monounsaturated	**8.46**	**4.23**
including:		
C14:1 (myristoleic)	0	0
C16:1 (palmitoleic)	1.78	0.74
C17:1 (heptadecenoic)	0.05	0.02
C18:1 (oleic)	6.42	3.36
C20:1 (gadoleic)	0.21	0.11
Polyunsaturated	**4.07**	**2.06**
including:		
C18:2 (linoleic)	3.88	1.98
C18:3 (linolenoic)	0.15	0.06
C20:4 (arachidonic)	0.04	0.02

In addition, the muscle tissue of turkey meat has a fine-fiber structure without "marbling", which allows to bind up to 40% of moisture, thereby increasing the output of finished products. Turkey thigh meat consists of several small dark muscles that determine the texture of the entire piece of meat and finished products. Consequently, the thigh meat of the turkey is very thoroughly mixed when used with other types of meat. Zhylovane thigh meat is made with the help of special mechanical devices that remove 13 existing thigh hocks. As result, we get raw materials similar to beef crushed in hasher with 2–3 mm holes. This meat can replace with lean beef or pork, for example, in the production of salami [22].

Turkey meat is common in meat industry for the production of cutlet semi-finished products, sausages and specialty foods, but requires mechanical processing such as meat massaging or tumbling. Strength characteristics of turkey meat, especially the femoral part, come from big amount of connective tissue, the amount of which increases with the age of the bird. In young poultry meat collagen does not greatly affect hardness, but the older the bird the stiffer is the meat, because of collagen that forms heat-resistant transverse and intermolecular bonds inside one molecule, forming a heat-resistant spatial mesh, the presence

of which causes the hardness of old birds meat. To increase the tenderness of turkey meat femoral part, different methods of mechanical processing, such as meat massaging or tumbling, are used. The promising trend is the use of enzyme preparations of plant and animal origin that have proteolytic activity, as well as probiotic cultures that secrete proteolytic enzymes capable of hydrolyzing the proteins of connective tissue [8].

The rapid growth of poultry meat production is due to the constant demand for it from consumers. There are no cultural or religious barriers for poultry meat. The consequence is the expansion of the range of products with poultry meat, the development of new recipes, new technologies that ensure the safety of products and their high quality.

Turkey meat contains all the necessary ingredients and can almost fully meet the needs of humans in animal protein. Given the high protein content and low fat, turkey meat can be used to produce cooked and smoked ham.

Study of the chemical composition of pumpkin seeds

The prospect for using oil-containing seeds to develop new meat products recepies is determined by its chemical composition. The chemical composition of oil-containing seeds crushed to a pasty mass is given in Table 4.

Table 4

Chemical composition of oilseeds [8]

Indicator	Mass fraction in the wall, %		
	Sesame	Sunflower	Pumpkin
Moisture	9.0	8.0	5.2
Proteins	19.4	20.7	34.2
Fats	48.7	52.9	31.4
Carbohydrates	12.2	10.5	17.6
Fiber	5.5	5.1	6.2
Ash	5.1	2.7	4.7

According to Table 4 it is determined that the protein content of oilseeds is indistinguishable from meat raw materials, and they can be considered as a good source of vegetable protein (19.4–34.2%). Protein content of pumpkin seeds exceeds meat protein content twice.

Sesame, sunflowers and pumpkin seeds contain a significant amount of vegetable fat (31.4–52.9%), it is opportune for the development of new products (increasing the content of the mass fraction of fat in raw materials causes a decrease in moisture content in the finished product, which is a positive factor for its use in the recipe of meat products).

Oilseeds are a source of carbohydrates, the total content of which (starch, mono- and disaccharides) is 10.5-17.6%. At the same time, plant raw materials also contain dietary fibers (up to 6.2%).

Biological value of sesame, sunflower and pumpkin seeds is determined by the presence of essential amino acids in the protein part (Table 5) and fat acid composition (Table 6).

Analysis of the amino acid composition of oilseeds proteins, the results of which is presented in Table 3, showed that they containe all essential amino acids, but there are minor differences in their quantitative content. In oilseeds, the predominant amino acid is leucine for sesame seeds, leucine and valine for sunflower seeds, phenylaline for pumpkin seeds.

Table 5

Content of essential amino acids in plant raw materials

Essential amino acid (EAA)	Content, mg/100 g		
	Sesame	Sunflower	Pumpkin
Isoleucine	783.0	694.0	656.7
Leucine	2338.0	1343.0	1792.0
Lysine	1074.0	710.0	624.6
Methionine	559.0	690.0	824.0
Treonine	1468.0	885.0	1601.0
Phenylalynine	1785.0	1149.0	2045.0
Valine	1296.0	1471.0	752.5
Tryptophan	590.0	348.0	389.2
Σ EAA	9893.0	7290.0	8685.0

Table 6

Fatty acid composition of plant raw materials

Fatty acids	Content, % to the total content of fatty acids		
	Sesame	Sunflower	Pumpkin
Saturated			
Palmitic ($C_{16:0}$)	4.20	3.22	10.51
Stearic ($C_{18:0}$)	2.20	3.90	5.37
Monounsaturated			
Miristoleic ($C_{14:1}$)	0.44	0.52	0.35
Palmitoleic ($C_{16:1}$)	0.10	0.20	0.10
Oleic ($C_{18:1}$)	25.40	17.60	44.69
Polyunsaturated			
Linoleic ($C_{18:2}$)	19.61	42.83	35.10
Linolenoic ($C_{18:3}$)	0.13	0.20	0.15
Arachidonic ($C_{20:4}$)	0.7	0.90	1.30

According to Table 3, it is determined that nonsaturated fatty acids (oleic and linoleic) that are involved in the formation of cell membranes and shells of nerve fibers prevail in oilseeds.

In addition, oilseeds have good mineral and vitamin composition: sesame seeds contain large amount of calcium, magnesium and phosphorus, vitamins PP, B_2; sunflower seeds are rich in selenium and vitamins E and B_1;pumpkin seeds contain in large quantities potassium, zinc, phosphorus and iron. Being rich in amino acids, fatty acids and minerals, the selected plant raw materials can be considered as an additional source of functional components with improved technological characteristics.

Pumpkin (Cucurbita) is genus of annual and perennial herbaceous plants, xenogamous, belongs to gourd family. Cucurbits are native to North and South America, where they are cultivated from the 3rd millennium BC. It is heat-loving, drought-resistant, relatively shade-tolerant plant. Pumpkin is juicy multi-seed fruit with yellow or orange pulp, from 15 to 40 cm in diameter. Seeds amount to 0.75–5% of its weight. The seeds are flat, elliptical, little narrowed on one side, 10–12 mm long. Outer shell is dense, woody, yellowish-white; inner

shell is scarious, greenish-gray. The seeds are without endosperm, large embryo consists almost entirely of two cotyledons. The taste of cotyledons is pleasant, buttery, sweetish. The seed shell makes in average 20–32% of the seed weight. The weight of 1000 dry seeds is 140–350 g.

Mainly, three species of pumpkin are cultivated: cucurbita maxima, cucurbita pepo and cucurbita moschata.

Cucurbita maxima is the most cold-resistant, but more late ripening variety than cucurbita pepo. Fruits are characterized by large size, long storage time, good flavours and multi-seeds (100–300g). The seeds are large (small ones are rare), milky white or brown depending on the variety, smooth, with an obscure border.

Cucurbita pepo is well adapted to sharp temperature fluctuations. The fruits are small, with hard rind and strigose subulate downiness. Seeds are usually of medium size or small, very rarely large, clear yellow or yellowish color, with a border of the same color [16].

Cucurbita moschata is the most heat-loving and late ripening one. The fruits are small and medium, of elongated shapes, narrowed in the middle. The fruit pulp is orange, with a nutmeg flavor. The seeds are elongated, medium or small, creamy or gray, with a border darker than the color of the seeds.

Unlike other crops, melons and, in particular, pumpkins are characterized by universal use. They are processed in canneries, used in medicine and pharmacology.

Due to the high content of sugars and biologically active substances, good taste characteristics, easy digestibility, pumpkin pulp has high nutritional and medicinal properties. The fruit pulp contains 70–94% water and 6–30% dry matter that contains 1.5–15% sugars; 4–23% fiber and hemicellulose; up to 24% starch; from 0.3 to 1.5% of pectins: 1–3% of nitrogenous substances; 0.5–0.7% crude fat, 0.1% acids; 0.4–1.4% ash; 25–40 mg% ascorbic acid; 2–28 mg% of β-carotene [10, 13].

For the processing enterprises the pumpkin is convenient in use because thanks to existence of dense pulp and biochemical features of structure, it is capable to be stored without deterioration of quality within 3–6 months [11, 12]. This allows you to reduce the seasonality of enterprises and load production in the autumn-winter period. During storage, the pumpkin ripens, besides the starch is hydrolyzed, the sugar content increases, its taste and nutritional properties improve.

Pumpkin is processed into pureed canned food for baby food and general purpose. Pumpkin is used for production of semi-finished products (boiled puree); it is used for juice production and pumpkin drinks blended with apricot, apple juices, flavored with orange oil, etc. Pumpkin is a valuable raw material for the production of pectin [14].

A by-product in the production of the above products are pumpkin seeds, which, at best, are used for livestock feed. At the same time, pumpkin seeds have a unique chemical composition and pharmacological properties, which are given to them by oil contained in the seeds. Pumpkin seed oil was recognized in the 1930s as a table product of industrial significance [9] (Table 7).

Table 7

Chemical composition of pumpkin seeds

No	Composition	Content (%, in equivalent to dry substances)
1	Water	6.02–6.50
2	Lipids	34.08–38.0
3	Protein (N-6,25)	31.0–32.5
4	Cellulose	13.58–18.10
5	Soluble carbohydrates	9.00–10.38

The content of oil in the kernel (in a shell-free seed) is 47.43–54.56%.

Phytosterol cucurbitol $C_{27}H_{46}O$, hydrocarbon $C_{30}H_{62}$ and oxycerotinic acid are found in the oil $C_{26}H_{52}O_3$.

The oil has a high content of biologically active substances, it contains 53 micro- and macroelements, carotene (provitamin A), tocopherols (vitamin E), vitamins B, PP and P [15] (Table 8, 9).

Table 8

Fatty acid composition of triacilglycerols of pumpkin oil

No	Composition	Content (% of fatty acids)
1	Palmitic $C_{16:0}$	6.0–12.5
2	Palmitoleic $C_{16:1}$	0.5–0.6
3	Stearic $C_{18:0}$	5.86–7.50
4	Eicosanoic $C_{20:0}$	0.003
5	Oleic $C_{18:1}$	26.0–36.0
6	Linoleic $C_{18:2}$	40.0–55.0
7	Docosanoic (behenic) $C_{22:0}$	0.2–0.25

Vitamin E is represented by a mixture of polyunsaturated fatty acids oleic, linoleic and linolenic, the content of which is up to 70%. Provitamin A in oil is represented as the sum of various carotinoids whose content is from 10 to 15 mg%. Vitamin E in pumpkin seed oil is in the amount of 94 mg% and it is represented mainly by α-tocopherol (76%). Vitamin E is one of the strongest natural antioxidants, which is of great importance for the living organism and provides high biological activity and quite good resistance to oxidation during oil storage.

Table 9

Content of micro- and macroelements in pumpkin oil

No	Composition	Content, mg%
1	Iron	13–15
2	Magnesium	3–4
3	Zinc	8–10
4	Selenium	5–6

Conclusion

1. The chemical composition, functional, technologicalб structural and mechanical properties of pumpkin seed flour and their change under the influence of technological parameters (table salt in solution, pH, temperature), including in combination with turkey meat, have been studied.
2. Qualitative indicators of turkey meat and skin, their chemical composition, functional and technological properties (moisture-binding, moisture-holding, fat-retaining, emulsifying ability, emulsion stability) were studied. The chemical composition of

turkey skin as a fat component of the meat emulsion was studied as turkey skin is a valuable raw material for production of ham.

3. Three experimental recipes for restructured ham were developed with the replacement of turkey meat with turkey skin in the amount of 10% and pumpkin seed flour in the amount of 5, 10, 15% hydrated in a ratio of 1:2.
4. Physico-chemical studies have shown that ham made with the use of turkey skin and pumpkin seed flour have slightly higher protein content and more balanced ratio of protein and fat in the recipe 1: 1, according to adequate nutrition,
5. Conducted functional and technological studies have shown that experimental ham is characterized by an increase in moisture-retaining and fat-retaining capacity. The test samples have the best moisture-binding, moisture-retaining, fat-retaining characteristics by 15%.

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Effects of cooking methods and new cultivars on physico-chemical properties of potatoes

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Abstract

Introduction. The aim of the study was to investigate the effects of cooking methods, i.e., boiling, pan frying, deep frying on total phenolic content (TPC), antioxidant activity % (AA) with DPPH (2,2-Diphenyl-1-picrylhydrazyl), trolox equivalent (TEAC), 2 2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), ferric ion reducing antioxidant parameter (FRAP), color and texture profile analysis (TPA) in five new cultivars (Fatih, Nahita, Nam, Onaran and Ünlenen) of Turkey.

Materials and methods. For analysis potatoes were used by fresh, and cooked by three different methods such as boiling (in soaked in cold water and boiled for 30 minutes), frying (Deep fried in corn oil in a large pan) and baking (at 220 °C for 45 minutes). TPC, AA with DPPH, TEAC, FRAP were determined by spectrophotmetric methods, texture parameters were determined by the texture analyser TA.HDplus and color was determined by a colorimeter.

Results and discussion. There were no significant ($p>0.05$) differences found between the TEAC, AA, ABTS and FRAP, values of the different potato cultivars. The effects of cooking methods on TPC, TEAC, AA, ABTS, FRAP, color and TPA were significantly different ($p<0.01$). The highest phenolic contents, TEAC, AA, ABTS, FRAP results were found in the pan fried samples 932,23±114,82 mg catechin /kg potato, 331.00±23.42 µg Trolox/g potato, 81.75±7.46%, 1830.60±961.66 µg Trolox/g potato, 6115.00±2164.91 µg Trolox/g potato respectively. Fresh and deep fried potatoes have the highest L^* values (75.68±0.69, 72.33±3.12 respectively) and pan fried samples has the lowest L^* values (64.31±10.16). The lowest a^* values observed at boiled samples (-3.92±1.59) and the highest was the pan fried samples (1.31±4.98). There was no significant ($p>0.05$) differences about texture profile parameters between the 5 different cultivars of potato. Texture profile analysis results of cultivars were, Hardness (1633.59-2065.92), Adhesiveness (-81.42-54.74), Springiness (1.83-4.06), Cohesiveness (0.68-0.80), Gumminess (995.17-1188.32), Chewiness (1410.36-2173.34), and Resilience (0.68-0.83).

Conclusions. TPC and antioxidant activities of pan fried samples are significantly higher from other cooking methods. The results may also help consumers for choosing the cooking method for health promoting compounds to human use. There is a need for further researches about the bio availability of nutrients from different parts of potatoes and new cultivars.

Introduction

Potatoes are consumed as a basic food in many countries of the world and are characterized by a high content of sugar, protein and vitamin C content. Fresh potatoes contain about 20% dry matter and 60-80% of this dry matter is starch. This makes them a good source of energy. Potatoes are weak in terms of fat content, but rich in vitamins such as B1, B3, B5, B6, B9, riboflavin, and minerals such as K, P and Mg [1]. Potato is an important food crop and it contains a wide variety of phytochemicals such as phenolic compounds, and these compounds are affected by several factors [2,3]. Due to their bioactivity, phenolics have beneficial effects on human wellness. These bioactive substances can be affected by processing conditions, cooking methods [3]. Palermo and co-workers [4] reviewed the effect of cooking conditions on the phytochemicals by two opposite opinions. One of the ideas is that as a result of thermal degradation, the concentration of these phytochemicals decreases, and the other is the softening of the matrix that acts to increase the extractability of phytochemicals.

The aim of the study was to determine and determine the effect of boiling, frying, roasting on TPC and DPPH, ABTS, FRAP, texture profile parameters of new cultivated five potato varieties (Fatih, Nahita, Nam, Onaran, Ünlenen) in Turkey.

Materials and methods

Catechin, 2,2-diphenyl-1-1picrylhydrazyl (DPPH), potassium persulfate, 2,2'-azinobis,-(3-tehyl-benzothiazoline-6-sulfonic acid), Folin-Ciocalteu phenol reagent, 2,4,6-Tris(2-pyridyl)-s-triazine(TPTZ), methanol were purchased from Sigma.

Sampling of potato tubers

The tubers of Fatih, Nahita, Nam, Onaran and Ünlenen (newly registered varieties) potato varieties were obtained from Potato Research Institute Niğde/Turkey. For further analysis potatoes were used by fresh, and cooked by three different methods such as boiling (in soaked in cold water and boiled for 30 minutes), frying (Deep fried in corn oil in a large pan) and baking (at 220 °C for 45 minutes). Two uniform tubers selected and used for cooking. Home type cooker and oven were used for cooking (OI636 cooktop and 9620 MI oven, Arçelik/Turkey). For further analysis potato samples were used after grinding. The analyzes were carried out in duplicate.

Proximate analysis

Average weight of tubers were found by weighting 4 uniform tubers of potatoes.

Extraction of potato samples

Phenolic isolation of samples was done by the method of Shahidi and co-workers [5]. According to this method one gram sample extracted with methanol (70%; 10 ml) for 3 times using a homogenizer (11.000 rpm;1 min) (Daihan HG-15D). Then the slurry centrifuged at 4000 rpm for 15 min. Methanolic phase was collected and evaporated by rotary evaporator (Scilogex-RE100) at 45 °C under vacuum. Methanol (25 ml) was added to the extracted phenolics and filtered by filter paper (Whatmann No:1). Extractions and all analysis given below were performed in 2 replicates.

Determination of total phenolic content

The TPC was determined according to Kaur and Kapoor [6]. Methanolic extract, distilled water and Folin Ciocalteu reagent (0.5:7:0.5 ml) were added to test tube and mixed for 3 min. Then sodium carbonate (20%, 2 ml) was added and mixed again. The solutions were kept in water bath for 1 hour at 25 ° C and then read at 720 nm. Results were expressed as mg catechin of fresh weight potato using a standard calibration curve of catechin (r>0.99).

Scavenging of DPPH radical

The method of Kasnak [7] was used for determining the scavenging of DPPH radical. The methanolic DPPH (0,4 ml, 96mg/L) and 1,6 ml of sample was mixed and left for dark for 30 min at room temperature. The absorbance was measured at517 nm against the blank. The results were shown as Trolox equivalent (mg TE/g fresh potato) through the calibration curve (r>0.99).

Also antioxidant activiy (AA) (%) was calculated according to the equation given below;

Antioxidant activity (%)= $[(A_{blank}-A_{sample})/A_{blank}]x100$

Scavenging of ABTS

Analysis of $ABTS^{\cdot+}$ radical scavenging activity was determined by the method of Re and co-workers [8] modified by Kasnak [7]. The absorbance of ABTS solution was set to 0.70±0.02 at 732 nm with methanol before analysis. The ABTS solution (990 µl) and the extract (10 µl) mixed and left for 30 min for incubation. The results were given as Tolox equivalent (r>0.99).

Ferric reducing power (FRAP) assay

Ferric reducing assay was performed by Benzie and Strain [9] method with slight modification. The FRAP reagent was freshly prepared by mixing acetate buffer, TPTZ solution, $FeCl_3.6H_2O$ in a ratio of 10:1:1 and adding 12 mL distilled water, at 37°C. The FRAP reagent: deionized water: extract/standard or blank were mixed (1.8: 0.18: 0.06 mL) in the same test tubes, and incubated at 37°C for 4 min; absorbance was read at 593 nm. The results were given as Tolox equivalent (r>0.99).

Color measurement

The color attributes of potato samples were measured by Ci64 (X-rite/USA). The color was expressed in L*a*b. Color parameters were measured against a white calibration plate and were directly obtained from the apparatus.

Texture profile analysis of potatoes

Texture of fresh and cooked potatoes was evaluated by subjecting each sample to a compression test using texture analyser TA.HDplus (Stable Micro Systems/UK) equipped with a 50N load cell. A flat plate (50 mm diameter) was used at a cross-head speed of 50 $mmmin^{-1}$ [10].

Statistical analysis

Statistical analysis of all data was performed using the software program SPSS (version 18.0). Multiple comparisons were done with Tukey's test.

Results and discussion

Total phenolic content

The TPC of fresh, boiled, pan fried and deep fried potatoes and potato cultivars are given in Figure 1.

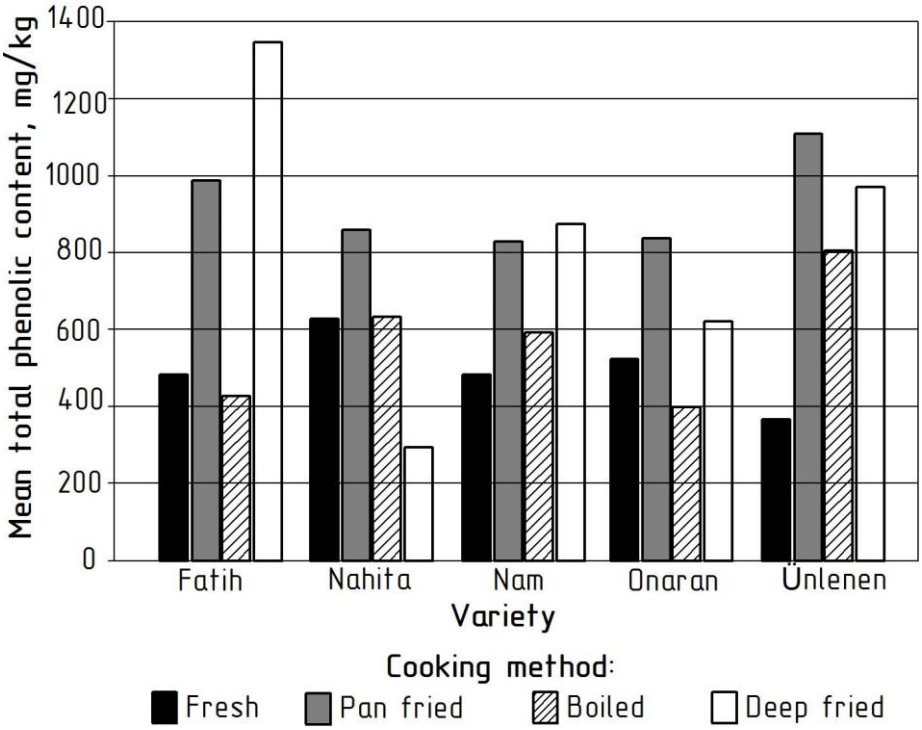

Figure 1. Total phenolic content (means±SD) of potato cultivars cooked with different methods

The highest TPC was found in the pan fried samples (932,23±114,82 mg catechin/kg potato) and were significantly different from fresh and boiled samples. The lowest TPC of the samples was found in fresh potatoes (500,93±90,68mg catechin/kg potato). There was no significant difference ($p>0.05$) were found between the potato cultivars TPC. The TPC of potato varieties vary from 604,50±173,61 to 819,46±302,74 mg catechin/kg potato. Figure 1 shows the TPC of potato cultivars cooked by different methods. Kaur and Kapoor [6] reported the phenolic content of potato 149,8±6.3 mg catechol/100 g sample, also Karadeniz and co-workers [11] found 553±102.5 mg catechin/kg fresh weight. Lachman and co-workers [12] found significant differences in TPC between yellow (2.46-3.44 g/kg dm) and

purple (4.55-4.81 g/kg dm) fleshed cultivars and also between yellow fleshed cultivars. Perla and co-workers [13] concluded that the lowest phenolic content of potato tubers was Russet Nugget (0.9 mg/g) and other tubers phenolic contents ranged between 1.2 and 1.9 mg/g. Also, they said that all the cooking methods reduced the TPC in all cultivars tested. However, Blessington and co-workers [14] reported an increase in TPC when tubers were baked, microwaved and fried, and no loss when boiled. They concluded that improving the extractability of phenolic compounds from the cellular matrix of cooked samples is responsible for this increase.

Antioxidant analysis results

According to antioxidant activity analysis results there were no significant differences ($p>0.05$) were found between the potato cultivars in the meaning of TEAC, AA, ABTS and FRAP. However, there were significant differences ($p< 0.01$) were found between fresh and cooked potato results. Rumbaoa and co-workers [15] reported methanolic extracts of potatoes have significant antioxidant activity and also reported a correlation between total phenolic content and DPPH radical scavenging activity. This indicates the phenolic compounds are responsible for the antioxidant activity. The same judgment has been given by Bellumori et al. [16] for TPC and ABTS values. Deng and co-workers [18] concluded that the thermal processing significantly increases the TPC and antioxidant capacities (DPPH, ABTS).

Pan fried samples have the highest amounts of TEAC, AA, ABTS and FRAP values. TEAC results showed that minimum values of Trolox equivalent antioxidant capacities antioxidant activity were in fresh group (254.35±38,04µg Trolox/g potato). All of the cooking methods significantly ($p< 0.01$) increase the TEAC. But there are not significant differences found among the cooking methods. Pan fried samples showed the highest TEAC (331.00±23,42µg Trolox/g potato). Table 1 shows the antioxidant activities of potato cultivars cooked by different methods.

Table 1

Effects of variety and cooking methods on antioxidant activities of potato tubers

	TEAC µg Trolox/g potato	AA (%)	ABTS µg Trolox/g potato	FRAP µg Trolox/g potato
Varieties				
Fatih	317,38±30,39	76,95±10,45	1101,25±596,86	3712,50±2062,63
Nahita	308,25±45,41	75,57±12,49	734,00±245,15	2875,00±823,54
Nam	290,00±45,87	67,29±16,00	800,75±240,98	2387,50±926,69
Onaran	275,63±47,08	62,06±16,52	861,25±685,64	2781,25±2579,34
Ünlenen	321,13±33,04	78,20±11,46	1509,50±1219,17	4587,50±2972,04
Cooking method				
Fresh	254.35±38,04[b]	56.31±13.25 [b]	411.20±60.41 [b]	2090.00±521.11 [b]
Pan fried	331.00±23,42[a]	81.75±7.46 [a]	1830.60±961.66 [a]	6115.00±2164.91 [a]
Boiled	306.10±37,56[a]	73.01±13.14 [a]	798.40±246.31 [b]	2025.00±769.92 [b]
Deep fried	318.45±25,78[a]	76.98±9.11 [a]	965.20±241.79 [b]	2845.00±1137.91 [b]

Data are expressed as means±SD (n=2). Values in each column having different letter are significantly different ($p<0.01$)

Table 2

Correlation between cooking method, total phenolic content and antioxidant activities

	TEAC	AA%	ABTS	FRAP
Cooking method	0,445**	0,420**	0,099 ns	-0,098 ns
Total phenolic content	0,539**	0,547**	0,653**	0,681**

**; Significant at 0.01 level,*; Significant at 0.05 level ns; Not Significant

Results show similarity with Blessington and co-workers [14] researches and they showed the antioxidant activity increase in the cooked samples of potato and they suggested that extractability of the antioxidant and phenolic compounds from the cellular matrix of cooked samples are responsible for this increase. The AA of fresh (56.31±13.25) potato samples were significantly ($p< 0.01$) lower than the other cooked (73.01±13.14 % to 81.75±7.46 %) potatoes. And there was no significant difference were found between the cooked samples. Bellail and co-workers [17] indicated an increase in the DPPH values of sweet potato root tissues cooked with different processing methods. They also reported thermal processing, increased the ABTS values more than DPPH. ABTS results showed that the pan fried potatoes were significantly higher ($p< 0.01$) than fresh and other cooked samples. FRAP results were similar to ABTS results.

Deng and co-workers [18] found FRAP, TEAC values and TPC of potatoes 10.85±0.77µmol Fe(II)/g fresh weight, 8.33±0.15µmol Trolox/g fresh weight and 7.16±0.05 mg Gallic acid equevalent /g fresh weight.

Colour measurements

Color parameters of potato varieties and cooked potatoes were given in Table 3. Color is the main parameter for consumer judges to buy food products. There was no significant difference were seen between the varieties in the manner of lightness and redness values. The highest b value was found at Fatih cultivar and there were no significant differences were seen with Nam and Ünlenen. And also there was no significant differencess were found between Nahita, Nam, Onaran and Ünlenen cultivars.

Table 3

Effects of variety and cooking methods on colour parameters of potato tubers

	L*	a*	b*
Varieties			
Fatih	68,80±5,70	0,08±3,54	32,46±6,14[a]
Nahita	68,25±6,29	-3,42±1,70	21,43±8,94[b]
Nam	74,72±5,24	-0,91±4,49	27,05±9,44[a,b]
Onaran	68,52±10,48	-1,60±3,44	20,60±2,95[b]
Ünlenen	70,10±6,51	-0,35±3,29	27,95±3,14[a,b]
Cooking method			
Fresh	75.68±0.69[a]	-1.57±0.30[a,b]	32.47±5.35[a]
Pan fried	64.31±10.16[c]	1.31±4.98[a]	26.14±8.16[a,b]
Boiled	68.00±5.09[b,c]	-3.92±1.59[b]	19.13±7.05[b]
Deep fried	72.33±3.12[a,b]	-0.77±3.01[a,b]	25.85±4.17[a,b]

Data are expressed as means±SD (n=2). Values in each column having different letter are significantly different ($p<0,01$)

Fresh and deep fried potatoes have the highest *L** values and pan fried samples has the lowest *L** values. The lowest *a** values observed at boiled samples and the highest were the other samples. Fresh samples have the highest b values and there was no significant difference were found between pan and deep fried samples. Also, there was no significant difference were found between boiling, deep and pan fried samples. Singh and co-workers [19] reported the *L**, *a**, *b** parameters of six varieties differs significantly. These parameters range between 68.6-73.9, -1.7- -2.8 and 21.5-28.6 respectively. According to Nourian and co-workers [10] L* value of boiled potato decreased and no major changes observed at *a** and *b** values. Pedreschi and co-workers [20] results did not show any changes in the manner of *L** and *b** values of potao chips, but at a values there was a progressive increase were seen with frying time.

Table 4 shows there was no significant differences about texture profile parameters (Hardness, Adhesiveness, Springiness, Cohesiveness, Gumminess, Chewiness, Resilience) between the 5 different cultivars of potato.

Table 4

Effects of variety and cooking methods on texture profile parameters of potato tubers

	Hardness (g)	**Adhesiveness (g.sec)**	**Springiness**	**Cohesiveness**	**Gumminess (g)**	**Chewiness (g)**	**Resilience**
Varieties							
Fatih	1901,16 ±1448,05	-60,34 ±67,59	2,84 ±2,79	0,72 ±0,12	1188,32 ±700,51	1493,42 ±499,73	0,74 ±0,33
Nahita	2065,92 ±2021,11	-65,69 ±74,21	2,36 ±2,05	0,68 ±0,14	1170,80 ±893,83	1410,36 ±197,87	0,68 ±0,34
Nam	1962,75 ±1475,53	-81,42 ±105,59	4,06 ±5,67	0,80 ±0,28	1160,00 ±623,80	1901,72 ±1423,21	0,83 ±0,55
Onaran	1749,68 ±1585,18	-54,74 ±95,94	3,47 ±3,84	0,69 ±0,15	1008,16 ±618,67	2173,34 ±1640,72	0,69 ±0,31
Ünlenen	1633,59 ±1298,20	-59,67 ±85,55	1,83 ±1,96	0,69 ±0,17	995,17 ±510,29	1440,83 ±1312,61	0,72 ±0,35
Cooking method							
Fresh	1416.08 ±322.91^{b}	-20.11 ±38.08^{a}	1.08 ±0.31^{b}	0.86 ±0.017^{a}	1111.00 ±212.26^{b}	1070.69 ±174.33^{b}	1.24 ±0.22^{a}
Boiled	4272.66 ±512.51^{a}	-192.99 ±34.66^{b}	0.54 ±0.04^{b}	0.48 ±0.036^{c}	2045.50 ±235.74^{a}	1124.29 ±155.69^{b}	0.35 ±0.04^{c}
Deep fried	537.89 ±234.78^{c}	-8.59 ±15.90^{a}	8.03 ±3.20^{a}	0.83 ±0.035^{a}	442.04 ±186.18^{c}	3191.95 ±1310.61^{a}	0.84 ±0.08^{b}
Pan fried	1223.86 ±609.05^{b}	-35.80 ±43.71^{a}	1.99 ±1.01^{b}	0.70 ±0.017^{b}	819.43 ±374.96^{b}	1348.81 ±671.22^{b}	0.49 ±0.02^{c}

Data are expressed as means

±SD (n=5). Values in each column having different letter are significantly different ($p<0,01$)

At the same time hardness values were increased when all of the potato varieties boiled. Before the texture analysis, boiled potatoes were cooled down during the preparation of samples so retrogradation of starch molecules may lead to an increase in hardness values. Singh and co-workers [19] concluded that differences between the textural parameters of raw tubers are due to the differences in their microstructure. Also, the resistance created by friction on the texture analyzer's bottom plate against the movement of the potato mass to the right and left in response to the force given to the boiled potato samples is thought to have caused the hardness value to be higher than the other samples. The lowest hardness values observed in deep fried group of potato samples. The highest adhesiveness value was detected in boiled samples while the lowest one was the deep fried samples. According to Table 4 springiness values of potato samples which cooked different methods were significantly different from each other. Cohesiveness of fresh and deep fried samples was significantly different from boiled and pan fried samples. Boiled samples has the highest and deep fried potatoes has the lowest gumminess values. There were no significant differences were found between fresh and pan fried samples. Deep fried potatoes showed the highest chewiness and significantly different from other cooking methods. And there were no significant differences were found between boiling, pan fried and fresh samples. Resilience of fresh samples was found significantly higher than deep fried and deep fried was higher than the other two cooking methods.

Dry matter and starch contents are responsible for the textural and rheological characteristics of raw and cooked tubers [21]. Shetty and co-workers (1992) concluded textural parameter changes are due to the physicochemical and cell wall structure changes. Also during the cooking various factors changes such as gelatinization, degradation of pectin etc. and affects the texture of the cooked potatoes. Nourian and co-workers [10] showed that the texture changes kinetics are due to the cooking of potatoes are functions of cooking temperature and time. Şerban and co-workers [22] showed that the boiling of potato varieties results with an increase in hardness values. According to Marle and co-workers [23]) adhesiveness of potato samples increased as a result of the temperature during cooking. They also concluded that it can be related to starch gelatinization and heated cells become filled with gelatinized starch so diminished the intercellular cohesion. Table 5 shows the significant ($p<0.01$) correlations between cooking method and springiness, gumminess, chewiness and resilience. Also, there was significant correlations between dry matter and hardness, springiness, gumminess, chewiness ($p<0.01$) and adhesiveness ($p<0.05$).

Table 5

Correlations between texture profile parameters and cooking method, dry matter, starch content

	Hardness	**Adhesiveness**	**Springiness**	**Cohesiveness**	**Gumminess**	**Chewiness**	**Resilience**
Cooking method	$0{,}031^{ns}$	$-0{,}168^{ns}$	$0{,}638^{**}$	$-0{,}204^{ns}$	$-0{,}136^{ns}$	$0{,}609^{**}$	$-0{,}409^{**}$
Dry matter	$-0{,}566^{**}$	$0{,}394^{*}$	$0{,}596^{**}$	$0{,}235^{ns}$	$-0{,}660^{**}$	$0{,}422^{**}$	$-0{,}132^{ns}$
Starch	$-0{,}009^{ns}$	$-0{,}024^{ns}$	$-0{,}138^{ns}$	$0{,}111^{ns}$	$0{,}097^{ns}$	$0{,}074^{ns}$	$0{,}492^{**}$

**; Significant at 0.01 level,*; Significant at 0.05 level ns; Not Significant

Conclusions

TPC and antioxidant activities of pan fried samples are significantly higher from other cooking methods. Followed by deep fried examples, but this cooking method increases the calorie of servings. TPC of the samples gave strongest correlations with antioxidant activity analysis and these results support literature information. When compared with fresh and pan-fried potato samples, the DPPH method revealed 1.3--1.45 times more antioxidant activity, while the ABTS and FRAP methods showed 2.92-4.45 times more activity at the pan-fried samples. The results may also help consumers for choosing the cooking method for health promoting compounds to human use. There is a need for further researches about the bio availability of nutrients from different parts of potatoes and new cultivars.

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Quality rating of desserts based on fruit and berry raw materials

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Abstract

Introduction. The aim of the study is to study the rating of the quality of desserts based on a fruit and berry blended semi-finished product with an increased antioxidant capacity and improved sensory indicators.

Materials and methods. Fruit and berry blended semi-finished product based on apple and banana. Research methods: expert evaluation method; rating method of 20 flavor profile portrait descriptors; profile method on a 10-point scale of correspondence of intensities of sensation of aromatic and taste properties; redoxmetry – determination of antioxidant capacity; *pH*-metry.

Results and discussion. The article presents the results of the influence of decisive factors for the formation of qualitative characteristics of innovative desserts – such as sambuk. The analysis of the system approach on increase of quality of production is carried out. A model of the technological system has been developed. An explanation of the values of each subsystem, its components and functions.

Evaluation of dessert quality indicators is determined by obtaining the average value of individual descriptors. Sensory characteristics of the innovative dessert: homogeneous semi-thick consistency; the color corresponds to the fruit and berry raw material, uniform over the entire surface; the taste and smell are clean. Based on the obtained results, the rating of innovative desserts was calculated. The sample of dessert «Apple-banana» has a higher rating – 96.815 points compared to the control sample «Apple» – 91.195 points, which is a value that is 5.8% more than the control.

The minimum theoretical value of redox potential (*RP*) for water-alcohol infusions was obtained, which has a value (Eh_{min}) from 277.2 mV («Apple-banana») to 412.8 mV («Apple»). The actual measured value of *RP* infusions (Eh_{act}) – from 126 mV («Apple-banana») to 318 mV («Apple»). The hydrogen index for water-alcohol infusions has a value of 4.12 *pH* units («Apple») to 6.38 *pH* units («Apple-banana»). Water-alcohol infusions from plant raw materials have values of regenerative capacity (reduction energy – *RE*) in the range from *RE* – 94.8 mV («Apple») to *RE* – 151.2 mV («Apple-banana»). For the restaurant business in the production of desserts is promising apple-banana composition, which received increased antioxidant characteristics.

Conclusion. The use of fruit and berry raw materials for expanding the quality of desserts using the method of a comprehensive quality criterion and calculation of the rating of desserts is substantiated.

Introduction

In modern conditions, consumers of restaurants recognize the quality of food (Shimmura et al., 2019) as a determining criterion (Matsuoka et al., 2020). «Food quality» means a set of characteristics that meet the identified or probable needs of the consumer. (Shimmura et al., 2020; Tanizaki et al., 2020). This involves the creation of new food that are in demand (Shimmura et al., 2020) by generating new ideas (Kim et al., 2018), taking into account the views of employees on business processes (development of innovative food, development of innovative drinks, improvement of existing technologies) (Shimmura et al., 2019).

To assess consumer quality of the restaurant's food, it is proposed to use indicators of the composition of the product range, its uniqueness, as well as the taste and appearance of food (Kuzmin et al., 2016; Muñoz-Leiva, Gómez-Carmona, 2019).

One of the directions of development of desserts (Saunders, 2020), in restaurants is the production of sweet food (Nepovinnykh et al., 2019) with the addition of vegetable raw materials and a high content of biologically active substances (Ferrante et al., 2020).

Currently, the use of vegetable raw materials (Andreou et al., 2018; Belemets et al., 2016; Fotakis et al., 2016; Hrabovska et al., 2018; Iannitti, Palmieri, 2009; Kochubei-Lytvynenko et al., 2017) in restaurant business is very relevant (Gubskyi et al., 2015; Deinychenko et al., 2020; Ianchyk et al., 2018; Niemirich et al., 2017; Sylchuk et al., 2017).

Current demand for high-quality vegetable raw materials involves the development of new technological methods for its preparation, with increased quality control, environmental friendliness, higher energy efficiency, lower cost and safer operation (Dainelli et al., 2008; Mujumdar, Law, 2010). These methods will allow to preserve biologically active substances (Swasdisevi et al., 2009) – volatile aromatic substances, phenolic compounds, reduce their losses (Pavlyuk et al., 2018), increase sensory properties (Mayor, Sereno, 2004).

Vegetable raw materials contain different chemical substances that display a broad spectrum of biological activities (Frolova et al., 2019; Gerolis et al., 2017; Kamdem et al., 2013; Pyrzynska, Sentkowska, 2019; Sentkowska, Pyrzynska, 2018; Siddiqui et al., 2018; Steenkamp et al., 2004; Wong et al., 2020).

They have gained growing interest among scientists and consumers due to their antioxidant properties (Breiter et al., 2011; Dube et al., 2017). The ability of plant phenolics to act as free radical scavengers has led to increased interest in their ability to act as antioxidants (Herrera et al., 2018; Humia et al., 2020; Keating et al., 2014; Oh et al., 2013). Antioxidants are able to reduce the output of oxidation products: hydroperoxides, alcohols, aldehydes, ketones, fatty acids.

At present, the antioxidant characteristics of all prescription components, food additives, biologically active substances and their combinations have not been sufficiently studied (Buglass et al., 2012; Grunert et al., 2018; Gullón et al., 2018; Gulua et al., 2018; Joubert, Beer, 2012; Kuzmin et al., 2020).

The most promising, due to high taste, tender, airy texture and attractive appearance, are jelly sweet food – «sambuk». Unfortunately, these products are high in calories – low in nutrients (Polyovyk et al., 2021).

Therefore, the issue of expanding the range, the search for new prescription components and processing modes, in order to meet not only the taste preferences of consumers, but also the growing demand for functional products for restaurants (Kim et al., 2018).

«Sambuk» as an independent dessert is an effective dish for targeted enrichment with vitamins, minerals, dietary fiber and natural antioxidants (Koretska et al., 2020).

«Sambuk» dessert has a low nutritional value due to the fact that the largest share in the

recipe is sugar, apple puree and egg white. These components provide strength and stability of the foam system and, due to the presence of apple pectin, promote the excretion of harmful substances from the human body. Sugar shows its technological properties, but gives the product excessive sweetness and high caloric content of the finished dessert (Alija, Talens, 2012; Koretska et al., 2020).

These circumstances determine the relevance of this work, which consists in the development of sweet food based on fruit and berry raw materials (Kurzer et al., 2020; Walrand et al., 2020) in the technology of restaurant business. Creating desserts with high antioxidant properties and improved sensory performance allows restaurants to create new food (Alija, Talens, 2012; García et al., 2015; Koretska et al., 2020), which distinguishes them from competitors, creating a favorable image of the institution, which cares about consumer protection.

The aim of the study is to study the rating of the quality of desserts based on a fruit and berry blended semi-finished product with an increased antioxidant capacity and improved sensory indicators.

To achieve this goal, the following research goals were set:

- Determine the minimum theoretical value of *RP* (Eh_{min}), the actual measured value of *RP* (Eh_{act}), the hydrogen index of water-alcoholic infusions.
- Determine the values of the antioxidant capacity of fruit and berry raw materials in water-alcohol systems.
- To study the profile criterion of quality and rating of desserts.

Materials and methods

Materials

The object of research – technology of desserts.

The subject of research: protein model samples with sugary foods; puree from fruit and berry raw materials; desserts.

The study used protein model samples with sugary foods; puree from fruit and berry raw materials: apple, banana; desserts based on fruit and berry puree.

To prepare extracts from fruits and berries raw, use the following main raw materials: ethanol, alcohol, water, cardboard filter.

Description of research procedure

Preparation of infusions. Fruit and berry raw materials weighing 4 g were placed into the glass bottles, were filled by 100 ml of alcohol solvent with volume fraction of rectified ethyl alcohol 40 %. The resulting infusions were cooled to 20 °C for 7 days, stirring periodically.

Next, the infusions were filtered and studies were performed to determine the indicators of active acidity, which was measured on a pH meter in the mode of pH measurement with a combined glass electrode. The redox potential (*RP*) was measured in the potential measurement mode with a combined redoxmetric platinum electrode.

Description of methods

Methods for determining antioxidant capacity

RP is an important indicator of the biological activity of solutions (Kuzmin O. et al., 2016; Merwe et al., 2017). It characterizes the deviation from the ionic balance of free electrons in a liquid medium. Changing the concentration of free electrons leads to a change in its electron charge and, accordingly, the *RP*. If the *RP* is positive, it indicates the oxidizing ability of the solution, negative indicates recovery ability. The value of *RP* allows to estimate the energy of processes, that is, characterizes the activity of ions in redox reactions (Bahir, 1999; Priluckij, 1997). Therefore, in order for the human body to optimally use in the exchange processes water-alcohol solutions and food, the *RP* values must correspond to the *RP* values of the internal environment of the organism, or have more negative values (Bahir, 1999).

To evaluate the antioxidant properties of the obtained water-alcoholic plant extracts, the method (Priluckij, 1997), based on the difference of *RP* in inactivated inorganic solutions and complex biochemical media. The main criteria of this method were its clarity, simplicity, specificity, reproducibility of results and efficiency. A number of researchers also emphasize that method allows to determine the total antioxidant activity of liquid products, including in total in a complex mixture, and multifunctional antioxidants (Kuzmin et al., 2016).

Formula (1) holds for inactivated inorganic solutions in equilibrium. This formula links the active acidity of the *pH* and the *RP* (Priluckij, 1997):

$$Eh_{min}=660–60\cdot pH, \text{ mV}, \quad (1)$$

where Eh_{min} – the minimum theoretically expected value of the *RP*;
pH – active acidity of the test solution.

Acquired *RP* values were compared with actual measurements of Eh_{act} solution. The change of the *RP* toward the recovery energy (*RE*) was determined by the formula (Priluckij, 1997):

$$RE = Eh_{min}–Eh_{act}, \text{ mV}, \quad (2)$$

where *RE* – the shift of *RP* to the side of recovered meanings (resilence);
Eh_{min} – minimal theoretically expected meaning of *RP*;
Eh_{act} – actual measured *RP*.

Expert method of sensory evaluation

The expert method of determination of values of indexes of quality is based on the account of opinions of group highly skilled specialists-experts. (The expert of − it a specialist on the certain type of object which owns the increased sensitiveness to properties of this object) (Kuzmin et al., 2016).

Sensory imaging method

Determination of quality indicators of desserts was carried out by visualization of sensory properties, taking into account the difference in descriptors. The assessment of the

influence of plant materials on the quality indicators of desserts was carried out using the criterion in the form of the sum of the products of the constituent indicators. An important feature of this criterion is that samples are rejected (through the established critical limit) in which at least one of the quality indicators has a false representation (characterized by a small value that is undesirable for desserts). The criterion for the quality of desserts in a geometric interpretation determines the optimal variant with the largest area of the quality polygon, built using normalized dimensionless quality indicators:

$$S = sin\frac{2\pi}{N} \cdot \sum_{j=1}^{N}(f_j \cdot f_{j+1})', \quad (3)$$

where f_i – the value of a specific indicator; N – the number of samples.

The determination of the weighting coefficients of individual indicators and their descriptors was carried out using the Delphi method, an expert method for each group of indicators according to the average values of the descriptors of this group, provided that the sum of the indicators of the group is 10 points.

Determination of the rating of desserts was carried out as the sum of the sets of values of the average indicators of the descriptors by the product by the weight coefficient for each descriptor.

Determination of the priority (rating) of desserts is possible provided that weighting factors are used (according to a 10-point system) and the main indicators are recalculated into rating values:

$$P = \sum_{i=1}^{n}(m_i \cdot p_i)', \quad (4)$$

where m_i – the value of the weighting factor;

p_i – value of the main indicator.

Results and discussions

The complex of theoretical and experimental studies made it possible to determine the direction and approaches to the development of scientifically based technologies of desserts such as «sambuk» prophylactic direction (Ferrante et al., 2020; Polyovyk et al., 2021).

The general characteristics of obtaining a complex indicator of the quality of a new product – a sweet dessert of the «sambuk» type have been substantiated (Table 1).

The creation of new prophylactic «sambuk» desserts provides for the following:

– scientific and technological substantiation of the recipe composition of desserts;

– determination of the main subsystems of dessert technologies that are being developed and their interrelationships;

– conducting an analysis of the functioning of the system and its effectiveness;

– research of quality indicators of the developed desserts;

– determination of the shelf life of finished products.

Dessert production technologies were formed on the basis of a system analysis, which provides for the branching of the production process as a system into subsystems, which makes it possible to obtain finished products with predictable properties.

Table 1

Innovation structure of a new product

Index	Characteristic
Object of study	Dessert technology
Urgency of the problem	− Improving the consumer properties of desserts; − Increasing nutritional value; − Increase/expansion of the existing assortment
Problematic element of the system	Physicochemical indicators (pH level, redox potential, renewal energy), sensory indicators
Solution option	Use of fruit and berry raw materials for the technology of sweet desserts
Product name	Blended semi-finished products from fruit and berry raw materials for the technology of sweet desserts
Product concept	Blended semi-finished products are ready-made semi-finished products, the technological properties of which allow them to be used as a basis for sweet desserts. The use of mixed semi-finished products is based on the enrichment of sweet desserts with useful nutrients, which leads to an improvement in sensory indicators, an increase in nutritional and biological value
Target segment	For use by a wide range of consumers
Competitive advantages	A multifunctional product with a balanced composition of biologically active substances
Sensory characteristics of the product	− Blended semi-finished product has a homogeneous half-thick consistency; − The color corresponds to the plant material, uniform over the entire surface; − Taste and smell are clean
Range	Formed due to the variable components of the fruit and berry raw materials of the blend

Taking into account the purpose of desserts, during the development of the technology, it became necessary to analyze the technological functions of the main components and adjust the recipe composition, which will make it possible to create a sweet dessert with an enriched composition presented in Table 2.

Table 2

Functions of structure-forming components and systems

The composition of the stabilization system	Technological function
Blended semi-finished product	Foam stabilization, gelation
Egg white powder	Foaming
Glucose-fructose syrup	Sweetener, foam stabilization
Water	Recovery, dissolution

In modern conditions, in the development of new types of food products, the profile method of sensory assessment and computer modeling are widely used. At the same time, using model samples with different content of the innovative component, researchers try to take into account all possible positive and negative aspects of the created product.

Formation of the quality of the dessert

The production of desserts requires quality control throughout the entire technological process of making a dish. The quality of the products of the establishments of the restaurant industry is formed at the stage of its development and is laid down in the regulatory documents. At the production stage, the necessary conditions are provided for preserving the properties of raw materials, imparting the desired technological and sensory indicators to the product, and neutralizing inedible components. Ensuring a given level of product quality depends on many factors, and above all on the clarity of the parameters formulated in the technological maps.

We analyzed (using the Ishikawa diagram) (Figure 1) the main factors that form the quality of a sweet dessert. This approach is a graphical way of researching and determining significant causal relationships and makes it possible to identify key relationships between various factors of the first order: raw materials and materials, manufacturing technology and process modes, equipment used, personnel qualifications and the duration of the technological process.

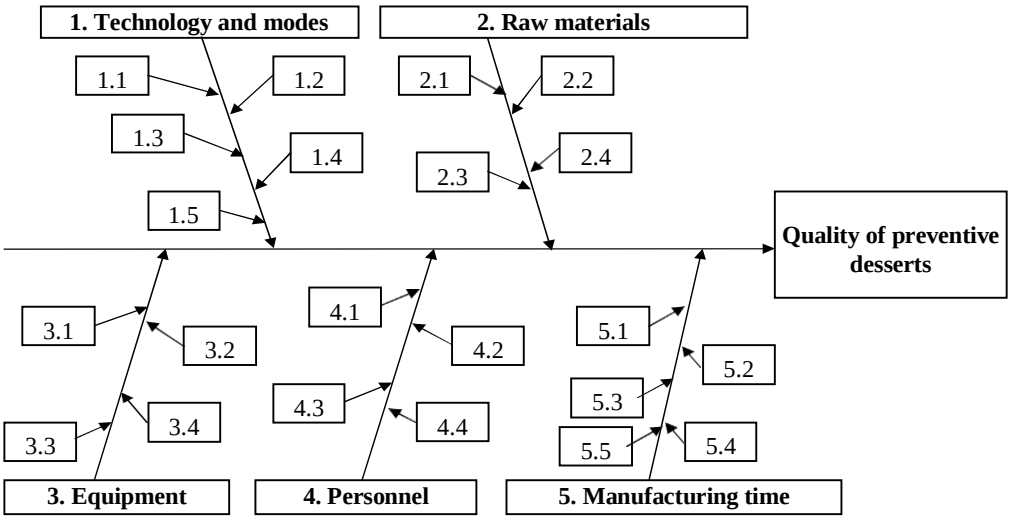

Figure 1. Causal diagram of the formation of dessert quality (Ishikawa diagram), second-order factors:

1.1 – compliance with the recipe; 1.2 – the sequence of introduction of components; 1.3 – compliance with the dosage of components; 1.4 – parameters of technological processes; 1.5 – sanitary and hygienic conditions; 2.1 – quality of basic raw materials; 2.2 – quality of blended semi-finished product; 2.3 – quality of auxiliary raw materials; 2.4 – compliance with the conditions of storage of raw materials; 3.1 – technical equipment of the enterprise; 3.2 – line performance; 3.3 – serviceability of equipment; 3.4 – the presence of control points; 4.1 – staff qualifications; 4.2 – experience of employees; 4.3 – diligence of staff; 4.4 – working conditions; 5.1 – timely preparation of components; 5.2 – timeliness of order acceptance (for restaurants) or availability of sales schedule (for sanatoriums); 5.3 – the presence of apples; 5.4 – the presence of berry raw materials; 5.5 – the presence of glucose-fructose syrup

For certain factors of the first level, we have established the factors of the second level, which are given under the main ones with the corresponding code. A number of factors are common in the manufacturing technologies of any culinary product and their effect is taken into account even at the stage of enterprise design. In order to improve the quality for ready-made desserts, it is necessary to take into account the effect of all factors in the technological process. Second-order factors that are specific in the manufacture of a certain dessert provide for the features of the technologies being developed.

Taking into account such approaches to the creation of a new product, the authors proposed a model of the technological scheme (Figure 2).

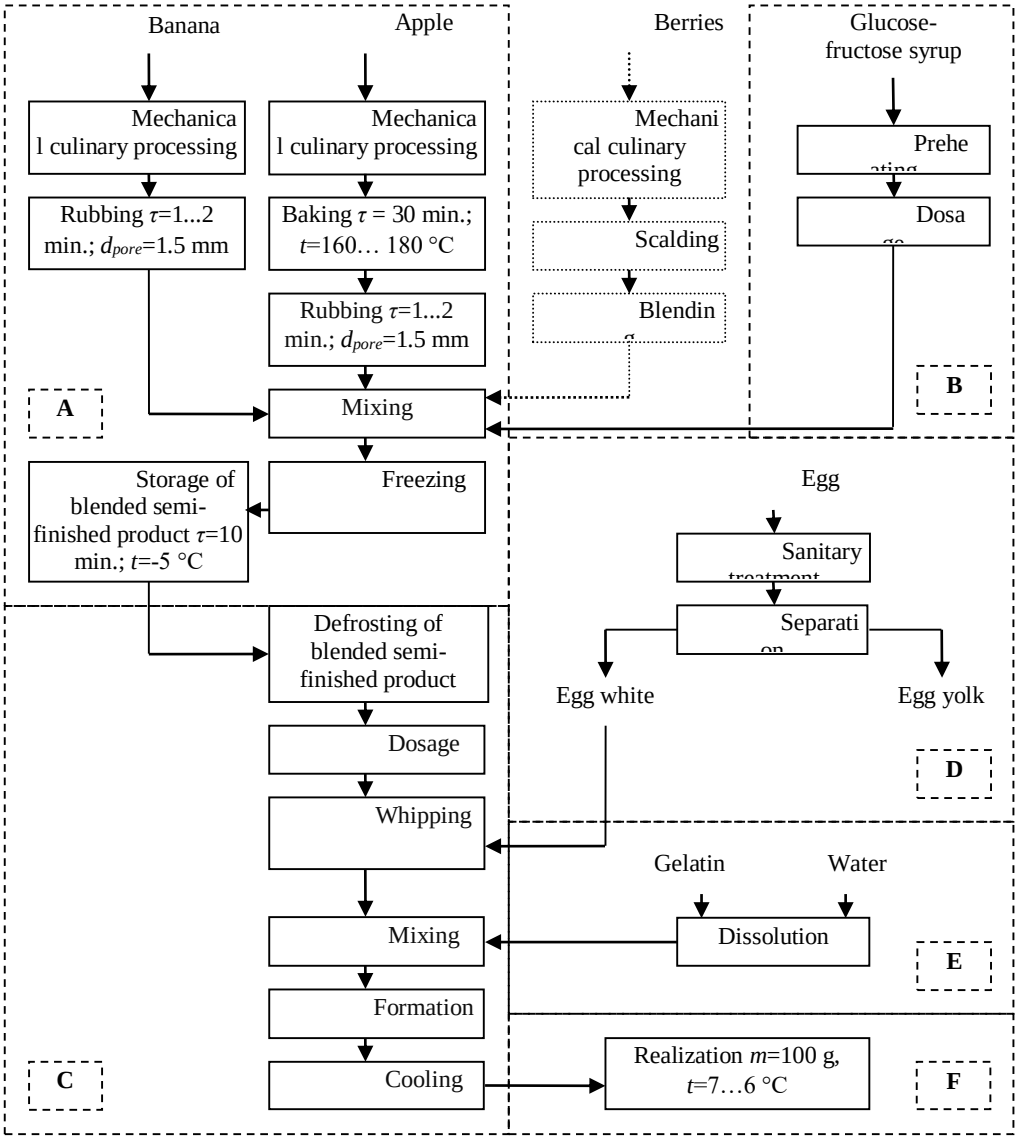

Figure 2. Model of the technological system «Production of whipped fruit and berry desserts of the «sambuk» type»

Functions of the subsystems of the models of the technological system «Production of innovative desserts of the foamy structure of the sambuk type»:

Subsystems A-F: obtaining a fruit and berry dessert of a frothy structure such as a whipped sambuk with specified quality indicators.

Technological operations are performed within the A-E subsystems. Subsystem F leads to the realization of the dessert.

Subsystem A performs the following technological operations: mechanical culinary processing, baking, rubbing, mixing, freezing, storage of blended semi-finished product. Subsystem A: search for the necessary basis for desserts by consistency, chemical composition and glycemic index; preparation and formation of recipe composition. Subsystem A can have several alternative solutions. For example, mashed from cranberries, dogwood and other berry raw materials can be made next to the apple puree shown in the principle technological scheme. In the given model, each of the subsystems has certain functions and tasks.

The developed technology for making desserts in the formation of subsystem A provides, first of all, the preparation of a blended semi-finished product from apples and other vegetable raw materials, which includes a number of technological operations to bring it to readiness.

Subsystem B performs the following technological operations: preheating glucose-fructose syrup and dosing it for subsystem A.

Subsystem C: an overview of technological approaches for creating a foamy base for the consistency of a dessert; obtaining a foamy consistency by determining the type and amount of the mass fraction of technological components, whipping time and mixing modes. In subsystem C the developed technology provides for the combination of vegetable fillers (blended semi-finished product, egg white, glucose-fructose syrup, water) and further whipping of the mixture.

Subsystem C: search for valuable plant raw materials from the point of view of chemical composition; study of the possible shape or consistency by introducing fruit and berry semi-finished products as part of desserts; development of a technology for the production of mixed semi-finished products; research of the desired component composition, the change or composition of which will make it possible to form an assortment of desserts.

Subsystem D: the study of the quality of egg white. Subsystem D provides for the use of egg white, which is used to replace the native one in desserts. At the stage of subsystem C, mixing of egg white with fruit and berry puree is provided (Precup et al., 2020; Seçmeler, Sevimli, 2020) and mixing with subsystem E (gelatin dissolved in water) and creation of a recipe mixture (Zeeb et al., 2020).

It is proposed to add blended puree from fruit and berry raw materials to the composition of the dessert in the form of a blended semi-finished product as a biologically active component that compensates for the lack of trace elements and vitamins necessary for the full functioning of the body (González-Herrera et al, 2016; Jatav et al, 2018; Kalinowska et al., 2014; Koutsos, Lovegrove, 2015; Marcus, 2019; Massini et al, 2018; Nitcheu Ngemakwe et al., 2017).

On the basis of the developed model of the technological system «Production of fruit and berry desserts of a frothy mixture», basic technological schemes for the production of fruit and berry desserts of a foamy consistency were developed.

Sensory evaluation

Based on the sensory assessment of sambuk samples, a quality criterion was calculated (based on the area of profilograms), which determines the overall comprehensive assessment of new desserts, and profilograms of the quality of sensory indicators for each dessert were constructed (Figure 3).

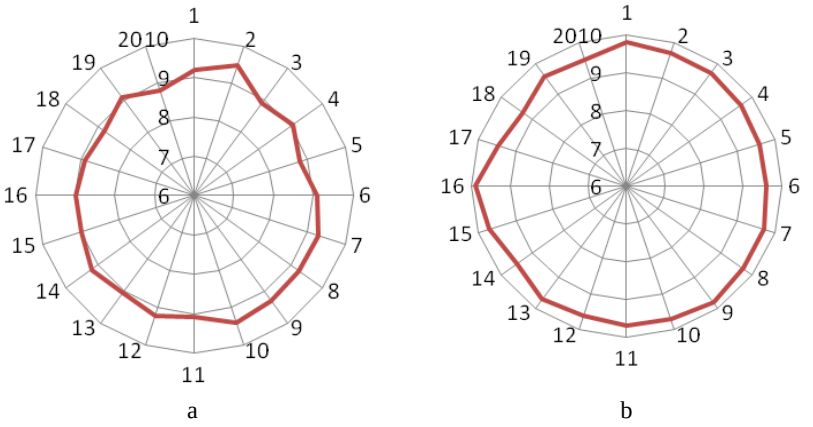

Figure 3. Dessert sensory profilograms:
a – apple; b – apple-banana; 1 – appearance; 2 – homogeneity of inclusions; 3 – naturalness; 4 – color; 5 – purity; 6 – uniformity of color; 7 – naturalness; 8 – taste; 9 – sweetness; 10 – intensity of the taste; 11 – uniformity; 12 – naturalness; 13 – smell; 14 – clean, 15 – expressive; 16 – balance; 17 – consistency; 18 – density; 19 – viscosity; 20 – fluidity

The quality of desserts was assessed by the following indicators: appearance (including color), taste, smell, and consistency. The value of the descriptors was taken into account when calculating the main indicator.

The weighting coefficients of individual indicators and their descriptors were determined by the Delphi method, by the expert method, for each group of indicators, according to the average values of the descriptors of this group and subject to the condition that the sum of the indicators of each group is 10 points (Table 3).

The final assessment of the quality indicators of desserts was determined by obtaining the average value of individual descriptors, which were used to determine this indicator by dividing the sum of the scores of all descriptors by their number. Using the results obtained, the desserts rating value was calculated.

The analysis of the rating of desserts showed that the sample «Apple-banana» has a higher rating indicator of 96.815 points compared to the control sample «Apple» (91.195 points).

The social effect of the new composition was confirmed – the preservation and protection of human health. This presupposes a more complete use of the nutritional potential of the raw materials used, an expansion of the assortment of desserts, an increase in their quality, an improvement in consumer properties, a decrease in the deficiency of vitamins, mineral elements and dietary fiber. This will ensure the normal functioning of the human body, satisfy consumer demand for desserts of functional importance.

Table 3

Indicators of the rating of desserts

Indicators, points	Significance factor	The value of individual indicators		Rating value	
		«Apple» (control)	«Apple-banana»	«Apple» (control)	«Apple-banana»
Appearance	3.0	9.20	9.80	27.600	29.400
Color	2.0	9.07	9.63	18.140	19.260
Taste	2.0	9.25	9.70	18.500	19.400
Smell	1.5	9.07	9.70	13.605	14.550
Consistency	1.5	8.90	9.47	13.350	14.205
Rating, points				91.195	96.815
Quality criterion, point[2]				1656.04	1860.56

Now at the international level there is an urgent problem of the production of desserts containing a high content of biologically active substances. Considering the dietary and functional purpose of desserts, it is advisable to introduce them into production, despite the increased selling price. New desserts can be consumed by all segments of the population, including those with diabetes mellitus.

Antioxidant capacity

Physicochemical studies, namely determination of the *pH* level and *RP* (Nicoli et al., 2004; Prévost, Brillet-Viel, 2014), were performed according to the method (Priluckij, 1997) and calculations given above (Kuzmin et al., 2016). As a result of extraction received infusions (Andreou et al., 2018; Iannitti, Palmieri, 2009; Kawa-Rygielska et al., 2019), physicochemical indicators (Breiter et al., 2011; Dube et al., 2017) of which are presented in the Table 4.

Table 4

Quality indicators of extracts on extractant

Plant raw materials	*t*, °C	*pH*	Eh_{min}, mV	Eh_{act}, mV	*RE*, mV
1. Apple (control)	20	4.12	412.8	318	94.8
2. Apple-banana	20	6.38	277.2	126	151.2

where: *t* – temperature of infusion; *pH* – active acidity of the test solution; Eh_{min} – minimal theoretically expected meaning of *RP*; Eh_{act} – actual measured *RP*; *RE* – recovery energy

Figure 4 shows graphically the change in the physicochemical indicators of the quality of extracts of raw materials on the extractant.

The minimum theoretical value of *RP* (Eh_{min}) for plant water-alcohol infusions (Priluckij, 1997) was obtained, which has a value from 277.2 mV («Apple-banana») to 412.8 mV («Apple»). The actual measured *RP* of infusions (Eh_{act}) was established – from 126 mV («Apple-banana») to 318 mV («Apple»). The hydrogen index for water-alcohol infusions

from raw materials has a value of 4.12 units *pH* («Apple») to 6.38 units *pH* («Apple-banana»).

Water-alcohol infusions from vegetable raw materials and a volume fraction of ethanol of 40% have the value of regenerative capacity (recovery energy – *RE*) in the range from *RE* – 94.8 mV («Apple») to *RE* – 151.2 mV («Apple-banana»). For the restaurant business in the manufacture of desserts, the apple-banana composition is promising, which has received increased antioxidant characteristics of *RE* – 151.2 mV.

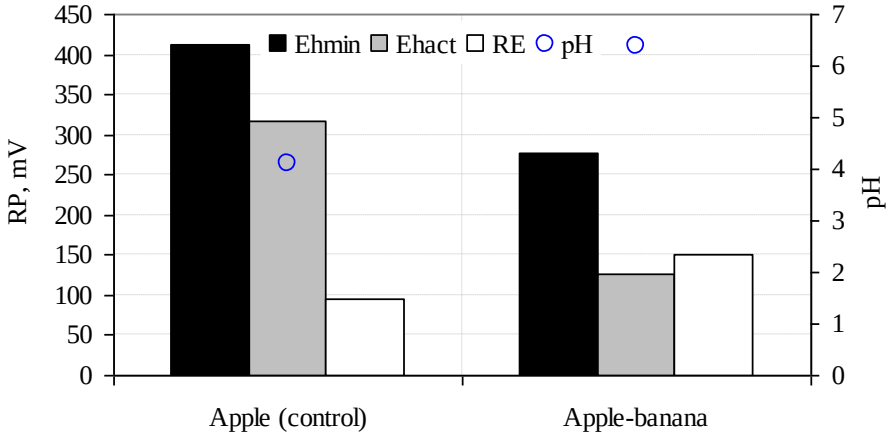

Figure 4. Physicochemical indicators of the infusions of the studied raw materials:
pH – active acidity of the test solution; Eh_{min} – minimal theoretically expected meaning of RP; Eh_{act} – actual measured RP; RE – recovery energy

The data obtained are correlated with the basic scientific concepts which are displayed in the works (Buglass et al., 2012; Frolova, Ukrayinets, 2018; Gerolis et al., 2017; Gullón et al., 2018; Gulua et al., 2018; Imark et al., 2000; Naithani et al., 2006; Naumenko et al., 2015; Pyrzynska, Sentkowska, 2019; Sentkowska, Pyrzynska, 2018), regarding the processes of extracting of plant materials. It allows to increase the antioxidant properties of the product (Breiter et al., 2011; Dube et al., 2017; Herrera et al., 2018; Keating et al., 2014; Vergun et al., 2019), will help to increase the immunity of the human body, improve the metabolism, positively affect the cardiovascular system, in addition it increases the consumer properties and will allow to reduce the cost of the finished product (Kumar et al., 2018; Peschel et al., 2006; Tan et al., 2020).

The development of a fruit and berry blended semi-finished product is a promising direction for increasing the nutritional value in the technology of desserts, expanding the assortment of the dessert group with predicted quality indicators. Its use ensures technological stability and high quality indicators of the finished product. The social effectiveness of the developments lies in the expansion of the assortment of desserts with a balanced dietary nutritional value and improved consumer properties.

Conclusions

1. Determined the minimum theoretical value of *RP* (Eh_{min}) for aqueous-alcoholic infusions, which ranges from 277.2 mV («Apple-banana») to 412.8 mV («Apple»). The actual measured value *RP* (Eh_{act}) is set – from 126 mV («Apple-banana») to 318 mV («Apple»). The hydrogen index for aqueous-alcoholic infusions ranges from 4.12 *pH* units («Apple») to 6.38 *pH* units («Apple-banana»).
2. The values of the antioxidant capacity of fruit and berry raw materials in water-alcohol systems have been determined. For the restaurant business in the production of desserts, the apple-banana composition is promising, which has received increased antioxidant characteristics of *RE* – 151.2 mV.
3. The profile criterion of quality and rating of desserts has been studied. An analysis of the dessert rating showed that the apple-banana sample had a higher rating score of 96.815 points compared to the apple control sample of 91.195 points.

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Functionality and chemical composition of maize-okara flour blends on biscuit quality

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Abstract

Introduction. Cereal grains are generally used as relatively inexpensive raw material in snack foods in developing countries. In order to enhance the nutritional quality of maize based flour, an attempt has been made to incorporate okara (a by-product) from soy milk production.

Materials and methods. Flour blends were developed by supplementing maize flour with okara flour (w/w) at 0, 10, 20, 30, 40 and 50% levels. The 100% maize flour served as the control. Biscuits were prepared from the flour blends. The functional and pasting properties of the blends as well as physical, chemical and sensory properties of the biscuit samples were determined.

Results and discussion. The flour blends developed in this study have distinct functional characteristics, providing added value to a waste product. Flour samples also varied significantly ($p \leq 0.05$) in the pasting properties. The results on biscuit samples revealed the following ranges: physical properties; weight 15.69 to 18.18g, diameter 11.39 to 13.62mm, thickness 1.59 to 1.71mm and spread ratio 6.99 to 8.06mm; Proximate parameters- moisture content 4.53 to 5.68%, ash 1.00 to 1.63%, protein 7.8 to 18.6%, fat 17.8 to 21.2%, fibre 1.91 to 5.28%, carbohydrate 47.6 to 67.0% and energy 392.50 to 409.58kCal/100g; anti-nutrients; phytate 0.03 to 0.06 mg/g, oxalate 0.36 to 0.73 mg/g and tannin 0.53 to 1.47 mg/g. The incorporation of okara increased the protein, fat and ash contents of biscuit samples while the carbohydrate content decreased. The biscuit samples presented different concentration of tannin; however samples prepared from 100% maize flour were devoid of phytate and oxalate. Sensory characteristics of biscuit prepared from 100% maize flour (control) varied significantly ($p \leq 0.05$) with those containing 10 to 50% okara inclusion level. However, biscuits containing 40% inclusion level of okara were most preferred.

Conclusion. The research work provide added value to edible waste product of food industries offering a promising alternative to address food and environmental problems in African tropics.

Introduction

Snacks are easy-to-prepare food eaten in place of a main meal or between main meals. Biscuit is a term used for a variety of baked, commonly flour based food product. They are nutritive snacks from unpalatable dough transformed into appetizing products through the application of oven heat [1]. Biscuits are widely accepted and consumed in many countries. The consumption of biscuits, wafers and short bread, has become very popular in Nigeria, especially among children and young adults [2]. Wheat flour is a critical and principal raw material in biscuit production. Its superiority over other cereals is due to the presence of gluten which confers unique texture and taste to wheat based products. Non-wheat flours are also used in baked goods with distinct attributes though they do not contain gluten. Some are particularly higher in protein, dietary fibre, phytochemicals and array of essential vitamins and minerals than wheat flour [3]. Non- wheat flours are obtained from other cereals, legumes, tubers, and root crops. Though, the utilization of these ingredients has gained ground in the production of snacks locally, but the use of composite flour of two important agricultural produce such as maize and okara (by-product from soy milk production) remain lesser known.

Maize (Zea mays) is an annual cereal crop belonging to the Poaceae family. Maize is one of the oldest cultivated grains and one of the most productive crop species with a global average yield of more than 4 tonnes per hectare [4]. Maize has been in the diet of Nigerians for many years and has been processed into a wide range of varieties by the different tribes in Nigeria usually done by cooking, roasting, frying, pounding or crushing to produce delicacies such as "tuwo", "ogi" and "dokunnu" as reported by Oladejo and Adetunji [5].The grains could also be processed into a wide variety of product such as starch, flour, grit, popcorn and breakfast cereals. Maize kernel is composed of 70–75% starch, 8–10% protein, 4–5% lipid, 1–3% sugar and 1–4% ash [6]. Maize germ contains about 45-50% oil which is made up of 14% saturated fatty acids, 30% monosaturated fatty acids, and 56% polyunsaturated fatty acids [7]. Most importantly, the yellow maize variety is a good source β-carotene (precursor of vitamin A) which is essential for good vision and at high concentrations also acts as a pro-antioxidant and induces apoptosis of colon cancer cells, leukaemia cells, melanoma cancer cells and gastric cancer cells, thus rendering potent chemopreventive effects [8].

Soybean (*Glycine max*) probably originated in Eastern China and is widely cultivated as a farm crop. It has been reported that soybean is a very rich source of protein, fat, phytochemicals and minerals such as copper, zinc and manganese [9]. Okara is a by-product from soy milk production; it is solid non-soluble fraction obtained from hydrothermal treatment of the crushed soybeans. This residue is generally discarded causing a significant environmental problem because it is susceptible to putrefaction due to its high moisture content (80%) as reported by Ostermann-Porcel [10]. Though Asian countries have found many ways to use okara, most other countries regarded it as agro waste with very little value hence used as animal feed. Okara has yellowish white colour with a neutral, smooth flavor. Asides, it is worthy to note that this by-product contains many beneficial components; hence it has attracted research interest as functional food. Okara is packed with a significant number of proteins, isoflavones, soluble and insoluble fibres, soya saponins, and other mineral elements, which are all attributed with health merits [11].

Maize is a cereal with miniscule protein content, and like other cereal grains; it is deficient in lysine and tryptophan while okara is a soy derivative that provides all the essential amino acids needed to fulfil human nutritional requirement for growth and maintenance [10]. Moreso, there is a high need for the development of gluten-free food in order to attend to an increasing food demand; hence, a source of suitable nutrients for celiac sufferers could be found in soybean derivative (okara) and maize.

The present study investigates the effect of supplementation of maize with okara on biscuit quality.

Materials and methods

Materials

Dried yellow maize (*Zea mays*) grains and soybean (*Glycine max*) were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan. The varieties used were Sammanz 35 (maize) and TGx 1835-10e (soybean) developed by IITA in collaboration with National Cereal Research Institute (NCRI). Other raw materials such as margarine, food grade salt, granulated sugar, food flavouring and eggs were purchased from a local market in Iwo, Osun state, Nigeria. The chemicals used for the analyses were of analytical grade.

Preparation of research samples

Okara flour. Okara flour was prepared using the method reported by Ostermann-Porcel [10]. Soybean (TGx 1835-10e) seeds were soaked in water for 8 hr at ambient temperature. The soaked seeds were ground in a blender with addition of water to enhance the grinding. The ground paste was then thermally treated at 90˚C for 20 min in order to reduce the activity of the trypsin inhibitor and deactivate the lipoxygenase enzyme which causes the unpleasant taste. The soybean slurry is separated from the ground paste using muslin cloth and the residue constitutes the wet okara. The residue was dried using laboratory drier and milled into flour using Phillip laboratory blender (HR2811 model). The okara flour was sifted using a 60 mm mesh, packed in glass container and kept in freezer (-4°C) pending analyses.

Maize flour. Fully dried yellow maize (Sammaz 39) seeds were weighed and manually sorted to remove bad grains and foreign materials. The sorted grains were weighed again and milled into flour using Phillip laboratory blender (HR2811 model). The maize flour was sifted using a 60 mm mesh, packed in glass container and kept in freezer (-4°C) pending analyses.

Experimental plan

Maize flour was supplemented with okara flour at 0% (sample A), 10% (sample B), 20% (sample C), 30% (sample D), 40% (sample E) and 50% (sample F). Table 1 shows the various ingredients in the preparation of biscuit samples.

Biscuits

Biscuit samples were produced from the blends using reported method [12]. Maize flour was supplemented with okara flour at 0, 10, 20, 30, 40 and 50%. After the baking process, the biscuit samples were allowed to cool to ambient temperature and packed in airtight glass containers for subsequent laboratory analyses. The biscuit samples prepared with 100% maize flour served as the control. Figure 1 shows biscuit samples prepared from the flour blends.

Table 1

Laboratory formulations of ingredients used in the preparation of biscuits (g)

Sample	Maize flour	Okara flour	Margarine	Sugar	Baking powder	Egg	Salt
A	300	0	50	30	0.05	90	0.5
B	270	30	50	30	0.05	90	0.5
C	240	60	50	30	0.05	90	0.5
D	210	90	50	30	0.05	90	0.5
E	180	120	50	30	0.05	90	0.5
F	150	150	50	30	0.05	90	0.5

A-100% maize flour;
B-90% maize flour + 10% okara flour;
C-80% maize flour + 20% okara flour;
D-70% maize flour + 30% okara flour;
E-60% maize flour + 40% okara flour;
F-50% maize flour + 50% okara flour

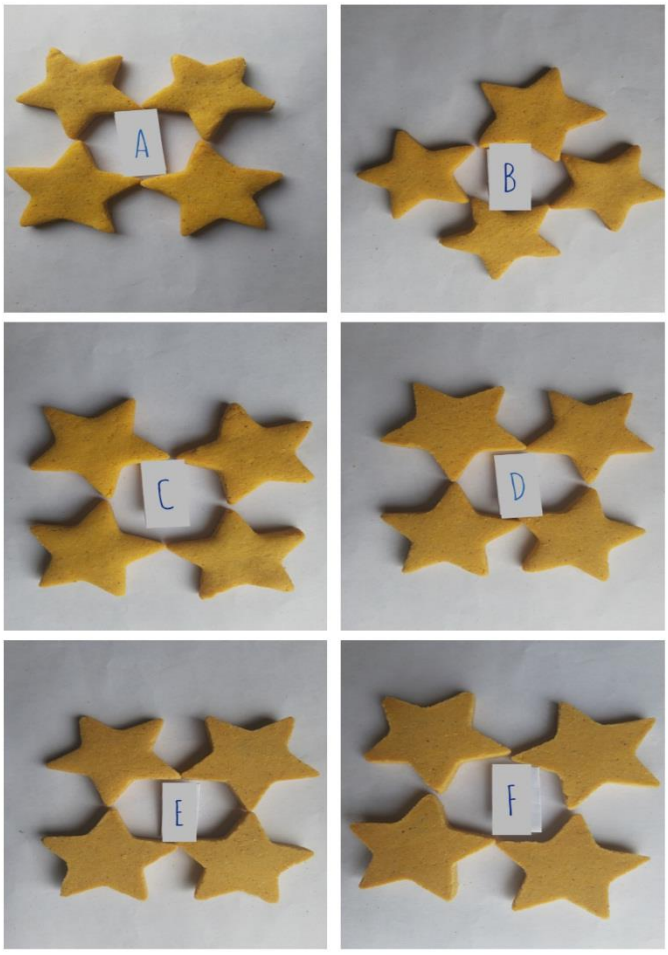

Figure 1. Biscuit samples with:

A-100% maize flour;
B-90% maize flour + 10% okara flour;
C-80% maize flour + 20% okara flour;
D-70% maize flour + 30% okara flour;
E-60% maize flour + 40% okara flour;
F-50% maize flour + 50% okara flour

Description of methods

Functional properties of flour blends. The bulk density (loosed and packed) of the flours was determined by the gravimetric method described by Appiah *et al* [13]. Water and oil absorption capacities were determined using the procedures described by Sofi *et al* [14]. Additionally, the swelling power and starch solubility of the flour samples were determined using the methods reported by Wani *et al*. [15].

Pasting properties of flour blends. The pasting behaviour of the flour samples was measured in a Rapid Visco Analyzer (Model: RVA-4, Newport Scientific Pty. Ltd., Sydney, Australia, 1995) and Thermocline for Windows software was used to evaluate the pasting properties.

Physical characteristics of biscuit samples. The biscuit samples were analysed for physical properties such as diameter, thickness, weight and spread ratio as described by AACC [16]. The surface colour of biscuits was determined according to values based on a CIE L*a*b* color scale using Konica Minolta Chroma Meter CR-400. All analyses were carried out in triplicate.

Chemical analyses of biscuit samples. Standard methods according to the AOAC [17] were used to determine the proximate composition. The caloric value was estimated (kCal/100g) by multiplying the percentage crude protein, crude lipid and carbohydrate by the recommended factors of 2.44, 8.37 and 3.57 respectively and then taking the sum as described by Ekanayake *et al* [18]. The titration method described by Oladele *et al*. [19] was used to determine the oxalate and phytate contents of biscuit samples. Tannin content was determined by the method described by Mugaboa *et al* [20]. All analyses were carried out in triplicate.

Sensory characteristics of biscuit samples. The sensory evaluation of the biscuit samples was performed by 25 semi-trained panellists. The panellists were asked to evaluate each sample based on the colour, taste, aroma, sweetness, hardness, crunchiness and overall quality using a 5-point Hedonic scale (5- like extremely and 1- dislike extremely).

Statistical analysis

Statistical analyses were conducted using Statistical Package for the Social Sciences version 17.0software (SPSS Inc., Chicago, IL, USA). Significant differences between the mean values were determined using Duncan multiple range tests at a significance level of $p \leq 0.05$.

Results and discussion

Functional properties of maize- okara flour blend

Functional properties of the flour blends were presented in Table 2. Supplementation of maize flour with okara flour had significant effect ($p \leq 0.05$) on the functional parameters under consideration. The loosed and packed bulk densities of the composite flours varied between 0.45-0.55 g/cm^3 and 0.62-0.72 g/cm^3, respectively.

Table 2

Functional properties of flour blends

Sample	Bulk density (g/cm^3) Loosed	Packed	WAC (g/mL)	OAC (g/mL)	Swelling Power (%)	Starch Solubility (%)
A	$0.55^{b}\pm0.02$	$0.70^{c}\pm0.01$	$1.91^{a}\pm1.02$	$1.45^{b}\pm0.07^{b}$	$6.89^{d}\pm0.09$	$12.79^{e}\pm0.72$
B	$0.47^{a}\pm0.02$	$0.72^{c}\pm0.01$	$1.90^{a}\pm0.13$	$1.44^{b}\pm0.35^{b}$	$5.88^{c}\pm0.09$	$8.19^{d}\pm0.20$
C	$0.48^{a}\pm0.00$	$0.67^{b}\pm0.00$	$2.38^{b}\pm1.24$	1.35 ± 0.60^{ab}	$5.79^{bc}\pm0.04$	$7.12^{cd}\pm0.11$
D	$0.48^{a}\pm0.00$	$0.63^{a}\pm0.00$	$2.37^{b}\pm2.03$	$1.36^{ab}\pm1.31$	$5.57^{bc}\pm0.14$	$5.92^{bc}\pm0.64$
E	$0.45^{a}\pm0.00$	$0.62^{a}\pm0.01$	$2.43^{b}\pm0.37$	$1.35^{ab}\pm0.04$	$5.54^{b}\pm0.13$	$5.12^{b}\pm0.81$
F	$0.45^{a}\pm0.00$	$0.62^{a}\pm0.00$	$2.48^{b}\pm0.80$	$1.09^{a}\pm0.41$	$4.99^{a}\pm0.17$	$3.03^{a}\pm0.49$

Key a-e: Means with the same superscripts within each row are not significantly different ($p\geq0.05$)

Highest values were identified in the control sample (100% maize flour). Lower bulk density of the composite flour blends gives an indication that they were lighter compared with the control. This might be due to the lower particle size of okara flour than that of maize flour. Such flour samples would be an advantage in preparation of complementary foods though their usage may produce less extensible and fluid dough due to high water uptake.

The water absorption capacity (WAC) of the flour samples varied between 1.91-2.48 g/mL and it showed a significant difference ($p\leq0.05$) with okara interaction. Composite flours had higher water absorption capacity than the control sample. This could indicate the fact that addition of okara flour improves the water absorption capacity of maize flour. This may be as a result of the increase in the protein content of blends containing okara compared with the control. Protein has both hydrophilic and hydrophobic properties, and so has affinity for water molecule in foods. Moreso, more hydrophilic constituents, such as dietary fibre contributes to high WAC in food ingredients.

Result shows that the maximum oil absorption capacity (OAC) was observed in the control sample, while the blend containing 50% maize flour and 50% okara flour had the lowest value. Significant decrease in OAC was observed as the percentage of okara flour in the blend increases. The decrease indicated the diluting effect of okara on oil absorption capacity of maize flour. It has been reported that variations in the content of non-polar side chains which might bind the hydrocarbon side chains of oil, explains differences in the oil binding capacity of flours [21].

Decrease in swelling power was noted in the flour blends as the level of okara increases. Swelling power of starch was reported to be inhibited by amylose and lipids [22]. In essence, the higher fat content observed in flour blends supplemented with okara was responsible for lower swelling power compared with the control. Reports on the relationship between swelling power, amylose content, lipids and amylopectin fine structure concluded that amylose and lipids inhibited swelling power while a high proportion of amylopectin long chains (DP > 35 unit chains) resulted in increased swelling power [23].

A decline in starch solubility was noticed in the flour samples as the level of okara in the blend increases. Higher solubility observed in the control sample compared with composite blends could be associated with high content of amylose which leaches out easily during the swelling process as reported by Sanni *et al* [24].

Pasting properties of maize-okara blends

Significant differences ($p \leq 0.05$) were observed among pasting properties of the flour samples as presented in Table 3. A peak viscosity of 30.34 RVU which was significantly different from other flour blends was observed in the control sample, while the least peak viscosity of 5.34 RVU was recorded in sample F. Blended flours recorded lower peak viscosity compared with the control. Peak viscosity is the maximum viscosity developed during or soon after the heating portion of the sample. It is often correlated with the final product quality and also provides an indication of the viscous loads likely to be encountered during mixing [25].

The trough viscosity ranged from 4.84 RVU in sample F to 26.78 RVU in sample A. The break down viscosities of the composite flour ranged from 0.05 RVU (sample E) to 3.55 RVU (sample A**).** It is an indication of breakdown or of the starch gel during cooking which often is used as an index of paste stability. The final viscosity ranged from 7.50 RVU in sample F to 72.56 RVU (sample A). The final viscosity indicated the re-association of starch granules especially amylose during cooling time after gelatinization [26].

This study showed a setback viscosity range of 2.64 to 45.78 RVU. Sasaki *et al.* [27] indicated that lower amylase content is associated with higher peak viscosity. Generally, the pasting viscosities and swelling power of flour are positively correlated [28]. Thus, the higher the swelling power of flour, the higher the pasting viscosities. The result corroborates the trend earlier observed on swelling power of the composite flour (Table 2). Variation exists in the peak time recorded for the flour samples. The pasting temperature of the control sample was significantly different compared with the blends containing different level of okara flour.

Table 3

Pasting properties of flour blends

Sample	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Setback Viscosity (RVU)	Peak Time (min)	Pasting Temperature (°C)
A	30.34 ±0.29^{a}	26.78 ±0.19^{a}	3.55 ±0.09^{a}	72.56 ±0.19^{a}	45.78 ±0.39^{a}	6.97 ±0.04^{a}	76.18 ±0.49^{ab}
B	19.91 ±0.29^{b}	17.25 ±1.44^{b}	2.67 ±0.14^{b}	42.86 ±0.67^{b}	25.61 ±0.54^{b}	7.00 ±0.00^{a}	74.77 ±0.49^{abc}
C	15.20 ±0.24^{c}	12.86 ±0.33^{c}	2.36 ±0.09^{c}	30.94 ±0.98^{c}	18.00 ±0.43^{c}	7.00 ±0.00^{a}	73.42 ±0.46^{bc}
D	8.97 ±0.19^{d}	7.92 ±0.14^{d}	1.05 ±0.04^{d}	15.75 ±0.50^{d}	8.17 ±0.14^{d}	6.95 ±0.00^{ab}	73.42 ±0.04^{c}
E	6.89 ±0.33^{e}	6.33 ±0.43^{e}	0.56 ±0.09^{e}	10.70 ±0.05^{e}	4.36 ±0.49^{e}	6.87 ±0.00^{b}	76.35 ±0.43^{a}
F	5.34 ±0.14^{f}	4.84 ±0.14^{f}	0.05 ±0.00^{e}	7.47 ±0.05^{f}	2.64 ±0.10^{f}	6.91 ±0.07^{ab}	74.97 ±1.27^{abc}

Key a-f: Means with the same superscripts within each row are not significantly different ($p \geq 0.05$)

Physical properties of biscuit samples

The physical properties of the biscuit samples prepared from maize and okara flour blends are shown in Table 4.

Table 4

Physical properties of biscuits with different level of okara

Sample	Weight (g)	Diameter (mm)	Thickness (mm)	Spread ratio	Colour attributes		
					L*	b*	a*
A	18.18 ±0.50^{a}	11.39 ±0.16^{b}	1.63 ±0.07^{a}	6.99 ±0.40^{ab}	85.69 ±0.06^{a}	0.88 ±0.09^{c}	24.56 ±0.06^{d}
B	17.72 ±0.80^{ab}	13.10 ±1.27^{a}	1.64 ±0.05^{a}	7.99 ±0.68^{a}	84.26 ±0.11^{b}	0.93 ±0.12^{bc}	25.96 ±0.18^{cd}
C	17.73 ±0.96^{ab}	12.90 ±0.97^{ab}	1.79 ±0.08^{a}	7.21 ±0.30^{ab}	83.60 ±0.19^{c}	1.12 ±0.03^{bcd}	26.67 ±0.11^{cd}
D	17.46 ±0.30^{ab}	13.07 ±1.02^{a}	1.63 ±0.02^{a}	8.02 ±0.59^{a}	83.31 ±0.21^{cd}	1.38 ±0.13^{a}	27.62 ±0.12^{c}
E	17.02 ±0.39^{b}	12.81 ±0.98^{ab}	1.59 ±0.26^{a}	8.06 ±0.92^{a}	83.18 ±0.07^{d}	1.15 ±0.10^{ab}	28.34 ±0.35^{b}
F	15.69 ±0.11^{c}	13.62 ±0.55^{a}	1.71 ±0.07^{a}	7.97 ±0.04^{a}	81.71 ±0.10^{e}	1.35 ±0.03^{a}	29.64 ±0.38^{a}

Key a-d: Means with the same superscripts within each row are not significantly different ($p \geq 0.05$)

The weight of the biscuit samples ranged from 15.69 to 18.18g. According to the results presented, the addition of okara flour into the formulation decreased the post-bake weight of the products. The reduction in weight is expected due to the fact that okara flour is less dense than maize flour.

The diameter of biscuit samples increased with the inclusion of okara in the formulation. The diameter of the control sample was the lowest (11.39mm) while sample F had the highest diameter (13.62mm). It has been reported that the use of non- wheat flour resulted in lower protein gluten and subsequent decrease in viscosity of biscuits dough [29]. Consequently, low dough viscosity results in high flow rate (spread rate) of the dough which contributes to the large diameter of biscuits prepared from composite flours. The thickness of sample E (1.71 mm) was highest while the lowest value was noted in samples A and D (1.63 mm). However, there was no significant difference in the thickness of the biscuit samples.

The diameter and thickness reflected in the spread ratio increased with increase in the level of okara in the formulation. The spread ratio of sample A was the lowest (6.99) while the highest was observed in sample E (8.06). The increase in spread ratio reflects poor cohesions of the net work of the protein and carbohydrates which are the major macro elements in the products. The poor cohesion could initiate the outflow of some ingredients such as sugar that could melt at high baking temperature hence increasing the spread ability of the material [30].

Evaluation of the surface colour of the biscuit samples across the space CIELAB indicated significant differences regarding the L*, a* and b* values. Comparing the L* values, statistically significant differences were found among the samples. Lower lightness (L*) values were observed as the level of okara increased in the biscuit samples. This is an indication that samples containing different level of okara flour present darker color compared with the control. The increase in color values could be attributed to the interaction between protein and sugar during baking which resulted in higher degree of Maillard reaction.

Similarly, the variation in composite formulation as marked by increase in the level of okara increased a* and b* values. Soybean contains high amount of carotenoid and there is retention of the pigment in okara flour. Similarly, the maize variety used in this study has yellow (carotenoid) colour. This explains reduction in L* value and predominance of redness (a*) and yellowness (b*) values observed in okara supplemented biscuit samples.

Chemical composition of biscuit samples

The proximate composition of the biscuit samples was significantly different at 5% level of significance as indicated in Table 5.

Table 5

Proximate composition of biscuits with different level of okara

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Carbohydrate (%)	Energy kCal/100g
A	4.53 ±0.81^{c}	1.00 ±0.26^{c}	7.79 ±0.01^{f}	17.77 ±0.01^{f}	1.91 ±0.64^{f}	67.00 ±0.19^{a}	406.93 ±1.03^{ab}
B	4.57 ±0.19^{c}	0.98 ±0.09^{c}	11.52 ±0.03^{e}	19.55 ±0.05^{e}	2.36 ±0.25^{e}	61.02 ±0.59^{b}	409.58 ±1.14^{a}
C	4.72 ±0.23^{bc}	1.26 ±0.25^{bc}	12.32 ±0.02^{d}	19.95 ±0.01^{d}	3.08 ±0.09^{d}	58.67 ±0.44^{c}	406.49 ±0.83^{ab}
D	4.80 ±0.15^{bc}	1.37 ±0.17^{bc}	14.37 ±0.01^{c}	20.42 ±0.02^{c}	3.86 ±0.16^{c}	55.18 ±0.20^{d}	402.97 ±1.00^{b}
E	5.04 ±0.06^{b}	1.53 ±0.13^{a}	17.86 ±0.01^{b}	20.64 ±0.01^{b}	4.46 ±0.16^{b}	50.47 ±0.61^{e}	396.51 ±0.97^{c}
F	5.68 ±0.25^{a}	1.63 ±0.08^{a}	18.62 ±0.02^{a}	21.15 ±0.01^{a}	5.28 ±0.56^{a}	47.64 ±0.69^{f}	392.53 ±1.11^{cd}

Key a-f: Means with the same superscripts within each row are not significantly different ($p \geq 0.05$)

Moisture content of the biscuit samples was within the range of 4.53 to 5.68%. The highest moisture content was noted in Sample F while there was no significant difference between other samples. The supplementation of maize flour with okara flour at 10 to 50% level significantly ($p \leq 0.05$) increased the moisture content of biscuit samples. This is attributed to the fact that the protein and fibre in soy flour are hygroscopic in nature hence absorb and retain higher amount of moisture during the baking process.

Significant difference ($p \leq 0.05$) was observed in the fat content of the biscuit samples. The fat content ranged between 17.8- 20.6%. The highest value of fat content was determined in biscuits prepared from 50% maize flour and 50% okara, whereas the lowest value of fat content recorded in biscuits prepared from 100% maize flour. The increase in fat content as the level of okara increases could be as a result of relatively higher amount of fat in the okara flour. Similar observation was reported by Rita and Adiza [31].

Data presented in Table 5 clearly show that supplementation of maize flour with different level of okara flour increased the protein content of biscuit samples. Protein content of biscuit samples ranged from 7.8 to 18.6%. The maximum protein content was found in biscuits prepared from the flour blends of 50% maize flour and 50% okara flour while lowest protein content was found in biscuits made from 100% okara flour. The protein content was observed to increase with progressive increase in proportion of okara flour. The increase might be due to the high protein content of soybean. The results of the present study are supported by the earlier report of Tasnima [32] that established an increase in protein content of biscuits prepared from soybean and wheat flour.

The ash content of the biscuit samples varied between 0.93 to 1.63%. The highest ash content was observed in samples E and F, while there was no significant difference between other samples. The result of this study indicated that the ash content was significantly higher in the biscuit samples containing okara flour compared with the control. This is an indication that okara flour is a good source of mineral elements. Earlier report had indicated that legumes are good sources of ash [32].

The fibre content of biscuit samples varied between 1.91-5.28%. Biscuits prepared from blends of 50% maize flour and 50% okara flour showed the highest value. In contrast, biscuit sample prepared from 100% maize flour had the lowest fibre content. The fibre content was observed to increase with the increase in proportion of okara flour in the formulation. Soybeans contain appreciable quantity of fibre and much more is expected in its residue after milk extraction. The increased fibre content of the biscuit sample is advantageous as it will prevent the indigestion often associated with products from refined grain flours. Asides, it has been reported that okara supplementation in human diet yielded a decrease in body weight, beneficial properties on lipid metabolism, protected the gut environment in terms of antioxidant status, as well as prebiotic effects [33].

The carbohydrate content of biscuit samples ranged between 47.6 to 67.0%. The highest value was observed in biscuit sample prepared from 100% maize flour whereas biscuit prepared from 50% maize and 50% okara had the least. It could be inferred that okara flour is not a good source of carbohydrate when compared with maize. Rita and Adiza [31] also authenticated that addition of soybean flour reduced the carbohydrate content in fortified biscuits.

The gross energy of biscuits samples varied from 392.53 to 409.58 kCal/100g. With the increase of okara, a significant decrease in value of kilocalories per 100 g was obtained. The slight decrease in the energy density of biscuit samples containing different level of okara was mainly due to the lower carbohydrate content than the control sample.

The oxalate content of the biscuit samples ranged from 0.37–0.73mg/100g as indicated in Table 6. The oxalate concentration was significantly affected by the proportion of okara in the formulation used for biscuit preparation. The highest oxalate content was determined in the biscuit samples containing 50% of maize and 50% of okara while the control biscuit contains no oxalate. In essence, the concentration of oxalate in the biscuit samples increased with the level of okara in the formulation. This is a clear indication that soybean contains oxalate. The presence of oxalate in the biscuit samples could have effect on nutrients bioavailability and absorption.

Table 6

Anti-nutrient composition of biscuits with different level of okara

Sample	Phytate (mg/g)	Oxalate (mg/g)	Tannin (mg/g)
A	ND	ND	0.53 ± 0.33^{a}
B	0.03 ± 0.02^{d}	0.37 ± 0.334^{b}	1.16 ± 0.33^{b}
C	0.04 ± 0.03^{cd}	0.49 ± 0.400^{b}	1.34 ± 0.33^{c}
D	0.04 ± 0.02^{bc}	0.67 ± 0.001^{a}	1.36 ± 0.33^{c}
E	0.04 ± 0.02^{b}	0.70 ± 0.113^{a}	1.41 ± 0.33^{cd}
F	0.06 ± 0.04^{a}	0.73 ± 0.020^{a}	1.47 ± 0.33^{d}

Key a-d: Means with the same superscripts within each row are not significantly different ($p\geq0.05$).
ND: not detected

Hence, oxalate is one of the factors to be considered during optimizing the proportion of okara supplemented with maize for biscuit production though the lethal dose of oxalate has been reported to be between 2 and 5 g/kg for man [34].

Phytate content of the biscuit samples ranged from 0.03 to 0.06 mg/100g. Biscuits prepared from 100% maize flour were devoid of phytate. The highest concentration of phytate was recorded in the biscuit samples prepared from the proportion of 50% maize flour and 50% okara. In present study, phytate content increased with increase in supplementation with soy okara in the biscuit samples. This might be due to the high amount of phytate content found in okara [35]. However, the quantity of phytate in the biscuit samples is below the recommended limit in the diet (250–500 mg/100g) as reported by Ekop *et al* [36].

Tannin content of biscuit samples ranged from 0.53 to 1.47 mg/100g and was significantly affected by the level of okara in the formulation. The highest tannin content was reported in the biscuit samples prepared from 50% of maize and 50% of okara while the lowest value was noted in the control sample. This indicates that the concentration of tannin in the biscuits increased as the level of okara in the formulation increased. Furthermore, the tannin concentrations in all the biscuit samples were below the level acceptable in a food which is 2g/100g [37]. Avoidance of products with levels of tannins exceeding this threshold should be a criterion in food selection.

Sensorial characteristics of biscuit samples

The sensorial ratings of the biscuit samples were presented in Table 7.

The highest colour score was presented in sample C followed by sample E and lowest for the control sample. However, there was no significant difference among the samples. This could be attributed to similarity in the colour of maize flour and okara flour. Both grains used in this study have yellow colour which made it difficult for the panellist to identify the difference as the level of okara in the blend increases.

Table 7

Sensorial characteristics of biscuits with different level of okara

Sample	Colour	Taste	Sweetness	Hardness	Crunchiness	Aroma	Overall acceptability
A	1.75 ±0.55^{a}	2.15 ±0.75^{a}	2.15 ±0.81^{ab}	2.20 ±1.11^{a}	1.80 ±0.77^{b}	1.80 ±0.77^{b}	1.95 ±0.67^{b}
B	1.80 ±0.77^{a}	2.05 ±0.95^{a}	2.00 ±0.73^{b}	2.45 ±1.19^{a}	2.00 ±0.80^{ab}	2.30 ±0.92^{ab}	2.05 ±0.89^{ab}
C	2.15 ±1.04^{a}	2.45 ±1.00^{a}	2.65 ±0.88^{ab}	2.40 ±0.94^{a}	2.65 ±0.88^{a}	2.70 ±1.03^{ab}	2.55 ±0.89^{ab}
D	1.90 ±0.85^{a}	2.30 ±1.03^{a}	2.50 ±1.05^{ab}	2.45 ±0.95^{a}	2.20 ±0.89^{ab}	2.25 ±0.97^{ab}	2.25 ±0.91^{ab}
E	2.05 ±0.76^{a}	2.70 ±1.03^{a}	2.95 ±1.15^{a}	3.10 ±1.02^{a}	2.80 ±1.06^{a}	3.05 ±1.36^{a}	2.80 ±1.15^{a}
F	2.00 ±0.80^{a}	2.60 ±0.95^{a}	2.40 ±0.94^{ab}	2.25 ±0.91^{a}	2.70 ±0.87^{a}	2.75 ±0.85^{a}	2.40 ±0.94^{ab}

Key a-e: Means with the same superscripts within each row are not significantly different ($p \geq 0.05$).

The scores for aroma ranged from 1.80 to 3.05. The highest value (3.05) was noted in sample E while the control sample had the least value (1.80). There was significant difference ($p \leq 0.05$) among the samples. Likewise, in term of taste, sample E was most preferred with a score of 2.70 while sample B was least preferred with a score of 2.05 although there was no significant difference among the samples.

There were significant differences ($p \leq 0.05$) between the samples in terms of crunchiness. An increase in the supplementation level of maize flour with okara resulted in higher scores which may be attributed to the low fat absorption capacity of okara flour as indicated in Table 2. The hardness measured by force applied to break the biscuits was significantly affected by increase in okara flour supplementation in the formulation. Biscuit sample containing different levels of okara are expected to be harder due to higher percentages of fibre and protein in okara which resulted in compact dough structure compared with the control. Moreso, the hardness of the samples containing okara can be attributed to higher water absorption capacity of the flour blends as indicated in Table 2. Earlier study had reported a positive relation between dietary fibre, hardness and chewiness [38].

The results indicated that all the biscuit samples presented good acceptability in terms of sweetness. Considering overall acceptability, sample E was most preferred among the biscuits produced from the flour blends. The result showed that supplementation of maize flour with different level of okara had minimal impact on the sensorial attributes of the biscuits.

Conclusions

1. In this study, it has been established that maize flour could be supplemented with okara flour to obtain biscuits with acceptable physical, nutritional and sensorial characteristics.
2. In terms of general acceptability, biscuit formulation of 60% maize flour and 40% okara flour was most preferred among the biscuits produced from the flour blends.
3. The study reveals that the application of okara could be widen with optimal conditions to generate not only nutritional benefits but also environmental significance.

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Rationale of fruit and berry raw materials choice to increase the confectionery nutritional value

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Abstract

Introduction. The aim of the study is to substantiate the choice of fruit and berry raw materials with high content of biologically active substances and to obtain a composition based on it to increase the confectionery nutritional value.

Materials and methods. Both traditional and non-traditional raw materials for marmalade production were studied: apples, plums, cherries, black currants, red currants, blueberries, cranberries, blackberries, sloe, viburnum, figs, gooseberries, goji berry, elderberry, black cherry, physalis. Using standard methods in each raw material determined the content of organic acids and pectic substances, both important and significant for marmalade production and the content of bioflavonoids, ascorbic acid, carotenoids and fiber, necessary to give the finished product health properties.

Results and discussion. It is advisable not only to expand the raw material base of the puree, but also to create blended compositions of puree for marmalade in order to increasing the nutritional value of the product, giving it health properties and creating competitive products on the market.

According to the established content in the studied cultivated and wild raw materials main biocomponents the following fruits and berries were selected: plum, black cherry and black currant.

The content of bioflavonoids, carotenoids and ascorbic acid is one of the highest in the selected berries of currant and black cherry among the studied samples at the same time with a high content of pectin 1.1%, fiber and organic acids. At the same time the plum was chosen as a significant source of pectin and organic acids, which are important for jellification.

Using of a chosen fruit and berry puree composition in the amount of 25–30% as part of the finished marmalade allows enriching it with a significant amount of biologically active substances, the content of which in a traditional product is insignificant.

Conclusions. The results showed the suitability of fruit and berry raw materials, including non-traditional wild, involving in the manufacturing of health products.

Introduction

Sugar confectionery, in particular the pastille-marmalade group, is in great demand among the world, especially children, due to its pleasant taste and appearance. However, unfortunately, this is most often achieved through the use of synthetic coloring agents and flavors, which do not have a positive effect, and in some cases their consumption has a negative effect on the human body [1, 2].

Currently, the world market does not have a wide range of herbal supplements from fruit and non-traditional officinal-technical raw materials (purees, pastes, concentrated juices, powders), which can be used to increase the biological value of jelly marmalade and as coloring agents [2, 8]. In addition, most of these additives involve strict technological processing of raw materials, during which coloring materials and nutrients are lost: vitamins, dietary fiber, organic acids, glycosides, etc. [6, 7].

The authors [21, 22] note that among plant additives, those with high coloring ability stand out.

Fruit and berry marmalade is of special value in the group of marmalade products [13, 23]. However, its production involves the use of apple puree, which is the main raw material of recipes and high requirements for it. The balance of acidity, water-soluble pectin content, its gelling ability allows to choose only certain varieties of apples for the production of puree. The decline of agriculture, the food-canning industry, significantly reduced the volume of apple puree with high gelling ability, which naturally affected the production of fruit and berry marmalade.

The use of purees of other fruits and berries in traditional marmalade technologies is quite limited [14]. Plum and apricot were used for the production of jelly drops, other species in very small quantities – as additional flavoring raw materials to expand the range [12, 17].

In the world market, marmalade products are mainly represented by jelly marmalade [27, 28]. Fruit and jelly marmalade occupies an intermediate position between the more scarce and useful fruit and berry and common jelly marmalade. By definition, it is made on the basis of gelling agents in combination with gelling fruit and berry puree.

It has already been noted that a number of authors [17, 25] aim to obtain confectionery products for health purposes, adjusting their chemical composition by using non-traditional raw materials suitable for the production of this products.

Thus, it is important to develop new types of these products using natural plant ingredients in order to expand the range, increase the biological value and create competitive products in the market.

The *aim* of the study is to substantiate the choice of fruit and berry raw materials with high content of biologically active substances and to obtain a composition based on it to increase the confectionery nutritional value.

Materials and methods

Fruit and berry raw materials

The subject of research is both traditional and non-traditional for the production of marmalade raw materials: apples, plums, cherries, black currants, red currants, blueberries, cranberries, blackberries, sloe, viburnum, figs, gooseberries, goji berry, elderberry, black cherry, physalis, fruit and berry puree, fruit and jelly marmalade for health purposes.

Using standard methods [29-31] in each of the raw materials types the main biocomponents content required for the production of health marmalade was determined.

Determination of pectin content

The content of pectin was determined by the weight method, which is based on determining the mass fraction of pectic acid by the mass amount of calcium pectate formed by the interaction under certain conditions of calcium chloride with pectic acid [32-35].

Determination of fiber content

Determination of the mass fraction of fiber is based on the decomposition of all other organic substances with concentrated nitric acid in a mixture with acetic and trichloracetic acids [32-33].

Determination of bioflavonoids content

The study of the total content of bioflavonoids in fruit and berry raw materials using Folin-Ciocalteu reagent and determination of the content of flavonols (mg/100g, in terms of rutin), anthocyanins by standard methodology of spectrophotometric method in the finished marmalade [31, 36, 37, 39].

Determination of carotenoids content

Quantitative content of carotenoids is determined by known spectrophotometric method [31, 39-41].

Determination of organic acid content

The organic acid content was determined by iodometric method, which is based on the reaction of sodium thiosulfate with iodine released by the interaction of free organic acids with a neutral solution of potassium iodide-iodate [31, 39-41].

Determination of organic acid content

Vitamin C content was determined using sodium 2,6-dichlorophenolindophenolate [31, 39-41].

Determination of sensory, physicochemical and rheological parameters of marmalade masses

The Reotest-2 device was used to study the change in the viscosity of marmalade masses in the process of marmalade boiling and selection of the optimal amount of fruit and berry raw materials. The shape, appearance, texture, fracture appearance, color, taste and smell of marmalade were determined sensoryally. Humidity, mass fraction of reducing substances, total acidity, mass fraction of ash were determined by methods of physicochemical analysis [29-31, 42].

Results and discussion

Obtaining a fruit and berry mix with a high content of biologically active substances, the most suitable for making marmalade

Marmalade products are dietary products due to the presence in their composition of gelling substances capable of removing heavy metal ions and radioactive ions from the body. However, the health effect of these products can be enhanced by the use in the technology of their production of fruits and berries, including wild, with predetermined healing properties [15, 18].

To evaluate fruit and berry crops that are the most suitable in marmalade production technologies, both cultivated and wild raw materials were studied: apples, plums, cherries, black currants, red currants, blueberries, cranberries, blackberries, sloe, viburnum, figs, gooseberries, goji berry, elderberry, black cherry, physalis. All these cultures are widespread in the Central and West Europe and have long been used in the diets of the population, as well as in folk and official medicine for the prevention and therapy of non-specific diseases [5, 6].

In our opinion, the choice of plant materials should be based on quantitative and qualitative ratios of a complex of biologically active substances synthesized in them by nature, sensory and technological properties of fruit and berry raw materials puree samples, most suitable for making marmalade.

According to the literature data [2, 18, 20].at approximately the same pH values for some samples of puree, the total acidity varies significantly. This is probably due to the high values of both organic acids in the chemical composition and other acid-reactive substances. This should be taken into account when creating blends of puree to ensure the gelling ability of the mixture, as well as taste, perhaps even without the addition of acids [18].

However, important and decisive for marmalade production from a technological point of view is the quantity and quality of pectin in the puree [38].

According to the technological tasks, for the formation of the jelly-like structure of marmalade there is a need to add to the system an additional amount of structurant [27, 42]. In addition to valuable technical properties, the range of their biological action is wide. Many pectins have an immunomodulatory effect and are able to remove heavy metals, biogenic toxins, xenobiotics, and metabolic products from the body.

Taking into account the above considerations, we determined these indicators in the raw material, summarized in Table 1.

Pectic substances are contained in all pods and berries (Table 1). Especially many of them in apples, black currants, cherries, gooseberries, black cherry. Also, a high content of organic acids is expected in all tested samples.

The importance of biocomponents in the composition of fresh raw materials, and in the obtained puree from them, is confirmed both by the technological suitability of this raw material and by clarification their role in the functioning of the human body [5].

An integral characteristic of fruit products intended for both fresh consumption and production of semi-finished and finished products is the amount of biologically active substances, including p-active substances, carotenoids, dietary fiber and ascorbic acid [43, 44].

Table 1

Experimental data to determine the content of dry matter, pectin and organic acid 100 g of raw materials as the main indicators that directly affect the production of marmalade

Test samples	Solids/%	Pectic substances/%	Organic acids/%
Apples	15.3	1.3	0.9
Cherries	14.5	1.0	0.8
Cherry	14.0	0.8	1.2
Plum	14.6	1.2	2.0
Black currant	13.5	1.1	1.8
Red currant	13.2	0.6	2.2
Blueberries	13.0	0.3	0.9
Cranberry	11.2	0.7	3.1
Sloe	17.3	0.9	2.8
Gooseberries	15.0	1.0	3.1
Figs	19.2	0.7	0.6
Blackberries	13.6	0.5	1.4
Viburnum	14.0	0.8	1.2
Goji berry	17.7	0.4	1.8
Elderberry	16.4	0.9	1.6
Black cherry	15.9	1.1	1.9
Physalis	10.2	0.9	1.2

n=3; p>0.95

Polyphenolic compounds are involved in redox reactions, respiration, nucleic acid formation and amino acid metabolism, protein synthesis, improve carbohydrate absorption. In addition, they normalize cholesterol metabolism, prevent the accumulation of harmful free radicals in body tissues, increase its resistance to infectious diseases and adverse external actions that cause overheating, hypothermia and oxygen deficiency, and human performance.

Bioflavonoids have a wide range of biological effects due to anti-allergenic, anti-carcinogenic, anti-inflammatory and antioxidant properties. These compounds contained in fruits and berries are able to remove alkaloid salts and heavy metals from the body and are characterized by antiviral and disinfectant effects. In combination with vitamin C, bioflavonoids allow to avoid many diseases, normalize the permeability of capillaries, maintain the elasticity of the walls and reduce the likelihood of internal hemorrhage [45, 46].

Carotenoids have anti-inflammatory and wound-healing properties, they regulate metabolic processes, act as photo protectors and antioxidants, prevent mutagenesis and carcinogenesis at the molecular and cellular levels, show radio protective activity and have a positive effect during pathogenic conditions caused by radioactive substances; effective in the treatment of xerophthalmia, improve fertility, growth and development of the young organism. Individual carotenoids (zeaxanthin and lutein) are an integral part of the retina and lens of the eye. Epidemiological studies have shown a direct dependence of the risk of age-related retinal degeneration and cataracts on the content of these carotenoids in the serum and disorders of their intake with food [47].

Fiber improves digestion, stimulates peristalsis, increases the rate of passage of food through the digestive tract, absorbs fats, toxins and mucus from the stomach and intestines and increases the absorption of nutrients. Fiber frees from toxins not only the digestive tract

but also the lymphatic system [33, 48].

These biologically active substances are important for the normal functioning of the body. Taking into account the above considerations on the relevance of use of non-traditional raw materials, especially rich in natural colorants, in the production of marmalade, identified these biocomponents, summarized in Table 2.

Analyzing Table 2, we can conclude that each type of fruit or berry has its own valuable biologically active substances, with which food products can be enriched. It is advisable not only to spread the raw material base of non-traditional raw materials, but also to create blended mixtures for marmalade in order to ensure its more valuable content of biologically active substances.

Table 2

Experimental data for determining the content of the main valuable biocomponents of traditional and non-traditional fruit and berry raw materials

Test samples	Bioflavonoids /mg%	Carotenoids /mg%	Vitamin C /mg%	Fiber, %
Apples	117	0.7	20	0.6
Cherries	1283	2.8	63	0.3
Cherry	1300	2.6	65	0.5
Plum	630	3.6	18	0.5
Black currant	1840	3.9	201	3.0
Red currant	1276	3.2	52	2.5
Blueberries	1985	1.3	57	2.6
Cranberry	975	0.9	34	2.0
Sloe	810	1.6	35	1.3
Gooseberries	829	3.1	61	2.0
Figs	347	2.0	10	2.7
Blackberries	2512	2.7	63	2.4
Viburnum	1328	2.4	42	1.9
Goji berry	1625	3.9	70	4.4
Elderberry	2379	1.5	59	3.7
Black cherry	2387	4.5	64	3.4
Physalis	796	0.8	54	1.9

n=3; p>0.95

Analysis and comparison of the data in Table 1 and Table 2 makes it possible to characterize each culture in terms of compliance with the next factors, namely to enrich the finished marmalade with bioactive substances of selected raw materials, while choosing the raw material that is most suitable for marmalade production. The studied cultivated varieties and wild species have a high content of certain biologically active substances: bioflavonoids, carotenoids, ascorbic acid and fiber. For some types of raw materials there is a correlation between the high content of biologically active substances in Table 1 and Table 2.

Apples, with a high content of pectin, balanced acidity and good gelling ability are traditionally used for the marmalade production [18, 26]. The selection of our samples was based on the choice of those fruits and berries that primarily have a high content of pectin, organic acids and colorants with a high content of all other specified and identified

biocomponents in Table 2. Our task was to select the plant raw materials, both rich in these biologically active substances, and the most suitable for the marmalade manufacturing. The following fruits and berries were selected according to the established and determined indicators: plum, black cherry and black currant. They have a high content of pectin and organic acids (Table 1). The following raw materials have a high content of bioflavonoids: blackberries, black currant, goji berry, black cherry, blueberry (Table 2).

Pectin content of blueberries, goji berries and blackberries is in the range of 0.3-0.6%. And the content of bioflavonoids, carotenoids and ascorbic acid (Table 2) is one of the highest in selected berries of currants and black cherries with a high content of pectin 1.1%, fiber and organic acids. The plum was chosen as a significant source of pectin and organic acids.

Obtaining fruit and jelly marmalade for health purposes on the basis of fruit and berry mix using unconventional raw materials

Fruit and jelly marmalade is obtained by traditional boiling of fruit purees, fruits, berries with sugar. In addition, pectin is used as a gelling base [26].

As functional enrichments for the marmalade production in this paper, it is proposed to use puree of plum, black currant and black cherry, selected from previous studies.

The puree was obtained by traditional technology [25–27], which includes the following steps: washing, inspection, steaming 3–8 min or blanching in water, pulping in a double pulping machine with sieves having holes of 1.5, 2.0 and 0.4–0.8 mm, the pulp was preserved by pasteurization at a temperature of 85 °C, as the most economical. This temperature promotes the preservation of labile substances, ensures the destruction of pathogenic vegetative microorganisms and allows obtaining a microbiologically safe product. Preservation of bioflavonoids is greatly enhanced by ascorbic acid, as polyphenols are able to suppress the action of ascorbotase, blocking copper in its composition, thereby slowing the oxidation of ascorbic acid, which has a stabilizing effect on bioflavonoids [44].

The obtained puree fully complied with the standards, and on their basis created a blend for later use for the production of fruit and jelly marmalade. It is established that to create a composition of fruit and berry mix, the optimal recipe ratio will be a ratio of 1:1:1 (puree of black currant, plum and black cherry, respectively).

Selected purees in certain quantities harmoniously complement each other's sensory properties, creating a functional enrichment with an original taste and pleasant aroma and a significant content of biologically active substances.

Subsequently, this ratio of the composite mixture was used to obtain marmalade.

The positive effect of marmalade depends on the mutual complex influence of all components and their quantity [10, 46]. The ratio of the ingredient’s composition is selected experimentally to ensure in the finished marmalade a high content of biologically active compounds inherent of its composition in raw materials. For this purpose, marmalade with a different percentage of fruit and berry puree addition, from 10 to 40%, was obtained.

The finished product had a pleasant smell and taste, attractive color when added to marmalade puree in the amount of 10-30%. When applying the composition of more than 30%, the color of the finished product is deep purple, unattractive to the consumer color and sour taste. Besides, the addition of the mix in an amount of more than 30%, leads to a weakening of the structure of the finished product, due to the sugar reduction in the recipe (less than 60%).

Therefore, the addition of a fruit and berry puree composition in the amount of 25–30% allows you to enrich the finished product with functional ingredients, as well as give it an attractive color.

During the fruit and jelly marmalade production, the recipe mixture together with the gelling agent contains white sugar, syrup, citric acid and fruit and berry puree. Since pectin is used as a gelling agent for the production of the developed marmalade, two main factors are needed to create optimal conditions for gelling – the content of a significant amount of sugar and an acidic environment [27, 42].

The first condition is fulfilled by introducing a significant amount of sugar into the recipe mixture. To create an environment with a low pH value in the industrial manufacturing of marmalade products the mixing in organic acids into the marmalade mass there is used. The practical norm of acid, in terms of malic acid, with a pectin content in the boiling mass of 0.8-1.0% and sugar content of 60–70% in the marmalade product is 0.8% [42].

We have made an assumption that it is possible to create an environment of low pH by using our chosen composition of fruit and berry mix, which contains a significant amount of free organic acids (Table 1).

The content of organic acids in the boiled marmalade mass was determined using apple pectin powder 1.0–1.3% and sugar 60–65%, syrup 5–7% and 25–30% of the fruit and berry mix composition. It was determined that the content of organic acids in the boiled marmalade mass is 0.8–0.9% and allows for normal jellification.

Thus the ratio of components in mass fractions: sugar 60–65%, the selected fruit and berry mix 25–30%, syrup 5–7% and pectin 1–1.3% allow obtaining the finished product of the desired jelly-like consistency with a dry surface and fine crystalline crust.

The main physicochemical (Table 3) and sensory parameters (Table 4) of the finished health marmalade were studied.

Table 3

Research of the basic physical and chemical indicators of a finished product

Product name	Humidity/%		Weight part of sugars/%		Total acidity/deg	
	Norm	Experiment	Norm	Experiment	Norm	Experiment
Fruit and jelly marmalade	15–24	21.3	Not more 25	21	7.5–22.5	9.7

The values of the main physicochemical parameters are obtained within normal range [42].

The sensory characteristics of the developed marmalade were analyzed (Table 4).

It is important that for the production of marmalade for health purposes there are used vegetable raw materials, which contain a significant amount of bioflavonoids, which are able to interrupt the chains of free radical oxidation reactions, i.e. have a powerful antioxidant effect. These substances help to protect cell membranes from potentially harmful effects or reactions that can be caused by excessive oxidation in the body, as well as prevent dysfunction of cell membranes, deterioration of health and premature aging [31, 45].

Undoubtedly that the plant-based materials present in the recipe of marmalade enriches the finished product with a significant amount of phenolic compounds, but they can be destroyed, as they are sensitive to any changes during the manufacturing process [29, 43].

Table 4

Sensory characteristics of the obtained marmalade

Indicator name	Characteristic
Taste and smell	Explicitly expressed. Specific to the raw materials from which this marmalade is made
Color	Smooth, homogeneous, purple. Specific to the raw material from which this marmalade is made
Consistence	Jelly-like
Form	Correct, without deformations
Surface	Dry, not sticky, with a fine crystalline crust or sprinkled with granulated sugar

Analysis of polyphenolic compounds content of the considered food systems was performed on the absorption spectra in the ultraviolet and visible regions of the spectrum. 10% ethanol extracts of marmalades: fruit and jelly, prepared using the proposed fruit and berry mix of plum, black currant and black cherry puree, and jelly – using only pectin as a gelling agent were prepared for this purpose. A spectrophotometer SF-26 was used to analyze the selected samples at the following values of wavelength. Catechins were determined at wavelengths of 250–290 nm, flavonol glycosides were determined at wavelengths of 320-360 nm, anthocyanins were determined at wavelengths of 520-560 nm.

The obtained results showed that the marmalade with the addition of fruit and berry mix compositions has a higher optical density.

According to the obtained data, the effect of marmalade enrichment with catechins, flavonols and anthocyanins was calculated. The results are shown in Table 5.

Table 5

Results of the obtained marmalade enrichment with catechins, flavones and anthocyanins

Original pectin based jelly marmalade (without the fruit or berry puree use)	Enrichment effect/%		
	Catechins	Flavonols	Anthocyanins
The original marmalade, enriched with a composition of fruit and berry mix of plum puree, black currant and black cherry	12.74	28.65	80.05

Thus, the use of the fruit and berry mix composition can significantly increase the content of phenolic compounds (catechins, flavonols and anthocyanins) in the finished product, which gives it new health properties.

Conclusions

1. Feasibility of new non-traditional raw materials using for the production of fruit and jelly marmalade, which allows expanding the range of marmalade products and the range of confectionery for health purposes is investigated and confirmed in this paper.
2. The use of raw materials, specifically the fruit and berry mix based on plum, black

currant and black cherry, in the technology of marmalade, allows enriching it with a significant amount of biologically active substances, the content of which in a traditional product is negligible.

3. Plant enrichment apolymeric flavonoid forms are able to quench radical reactions in the body and they better combined with carbohydrate products. Simple sugars immediately enter the bloodstream and bring antioxidants from plant materials.

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Functional and technological properties of food nanoadditive based on double oxide of ferrous and trivalent iron in production molded jelly marmalade

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Abstract

Introduction. The functional and technological properties of food nanoadditive based on double oxide of divalent and trivalent iron "Magnetofood"(Fe_3O_4) in the production of molded jelly marmalade were studied.

Materials and methods. Prototypes of molded jelly marmalade on agar and pectin. Functional and technological properties were studied with the help of Sensory (taste, smell, color, consistency, shape and surface – on a 5-point scale); physico-chemical (mass fraction of moisture, total acidity, determined by gravimetric and titrimetric methods, respectively); structural and mechanical methods. The strength of the marmalade well was determined by the shear stress on the penetrometer AP-4/1.

Results and discussion. The ability of nanoparticles of food additive Fe_3O_4 "Magnetofood" to promote: improvement of Sensory characteristics of molded jelly marmalade: the shape, surface and consistency is improved by 0,1–0,2 points (for agar marmalade) and 0,1–0,3 points (for pectin marmalade); increase in the moisture content by 1,15–1,16 times in the experimental samples on agar and 1,13–1,14 times in the experimental samples on pectin due to the moisture-binding and moisture-retaining ability of the chemically active nanoparticles of the additive "Magnetofood"; reduction of the total acidity by 1,05–1,08 times in the test samples on agar and 1,06–1,09 times in the test samples on pectin due to the amphoteric and sorption properties of the additive.

The strength of jelly-marmalade jelly was increased by 1,3–1,5 times (for agar marmalade) and 1,22–1,4 times (for pectin marmalade) with the introduction of 0,1–0,2% "Magnetofood" due to the structural and stabilizing action of the nanoparticles of the additive. The rational content of the food additive "Magnetofood" was determined – 0,15% by weight of the prescription mixture for both gelling agents (agar and pectin).

The optimal conditions of temperature-humidity regime during storage of molded jelly marmalade are established: relative humidity φ=(75±2)%, temperature (18±2)°C, recommended storage duration is 90 days.

Conclusions. For the first time, the functional and technological properties of food nanoadditives based on double oxide of ferrous and trivalent iron in the production of molded jelly marmalade were studied.

Introdaction

Jelly-marmalade products have a colloidal dispersed structure, so the problem of its stabilization is relevant. In addition, in the conditions of competition in the domestic market, manufacturers of jelly and marmalade products are looking for ways to increase their competitiveness by improving the functional and technological characteristics of raw ingredients; consumer properties of finished products, reducing the cost and extending their shelf life [1, 2]. To improve the structural and mechanical properties of gel-like masses and consumer characteristics of finished products, non-traditional raw materials are used, such as waste from the food industry (Canning, wine, sugar beet industries) and agriculture (seed State Farms, Cotton, melon) [14-16]; as well as alternative raw materials: chitosan, vegetable, vegetable and fruit and vegetable products [17, 18] in that puree feijoa, Kiwi, Jerusalem artichoke [19, 20]; extracts and powders of spicy-aromatic herbs and vegetable, fruit and Berry powders (help to improve the consistency and consumption characteristics of the finished product (their disadvantage is insufficient stability of the gel-like structure) [21, 22]; sorbitol [23]; hydrocolloids: carrageenan and its sodium, potassium, ammonium salts, including furcellaran; xanthan, tari, guar gum, carob gum, xanthan gum, etc. (help to increase moisture-retaining ability and improve elasticity – elastic properties of jelly-marmalade products with a long shelf life) [4, 5, 8-10]. Combined systems of structure – forming agents are widely used, in particular combinations of gelatin with pectin, with sulfated polysaccharides, gelatin-K – carrageenan, gelatin-pectin LM [5, 7, 8]; pectin with hydrocolloids (Herbagel SW – 010, rikogel 8100), pectin LM-K-carrageenan [7, 10]; Agar with animal protein concentrate "Scanpro" [4, 11]; various modifying systems: sodium-carboxymethylcellulose (S-CMC) with iron chloride [4, 7]; sodium lactate, sodium citrate with glycerin [10, 11], mannite or sodium alginate [12, 13]; modifications of metal nanoparticles and their oxides with polysaccharides, vegetable and animal proteins: egg and whey protein albumin, gelatin, whey protein, gliadin, legumes and soy proteins, elastin, Zein, milk protein [24-28].

Analysis of literature sources [1-28] showed that there is insufficient data on the effect of nanoadditives, in particular, food nanoadditives based on double iron oxide ("Magnetofood") [UA Patent No. 126502] on the physico-chemical, structural-mechanical and Sensory characteristics of molded jelly marmalade. Food nanoadders "Magnetofood " (Fe_3O_4) have a wide range of functional and technological properties (structure-forming, stabilizing, sorption, etc.) and promising technological applications [29, 30].

In this regard, the study of the functional and technological potential of the food Nano-supplement " Magnetofood " in terms of its impact on the quality and timing of preserving the freshness of jelly and marmalade products is relevant.

The aim of the research is to determine the functional and technological properties of a food additive based on double iron oxide "Magnetofood" (FAM) in the production of molded jelly marmalade on agar and pectin.

To achieve this goal, the following tasks were set:

- to study the effect of the food additive "Magnetofood" on Sensory parameters (taste, smell, color, consistency, shape and surface) of experimental samples of molded jelly marmalade on agar and pectin;
- to study the effect of the food additive "Magnetofood " on the physical and chemical characteristics (mass fraction wet, total acidity) of prototypes of molded jelly marmalade on agar and pectin;

- to study the effect of the food additive "Magnetofood" on the structural and mechanical properties (strength of jelly-marmalade jelly) of prototypes of molded jelly marmalade on agar and pectin;
- to establish the rational content of the food additive "Magnetofood" and optimal conditions for the temperature and humidity regime during the storage of molded jelly marmalade on agar and pectin.

Materials and methods

Materials

Object of research: functional and technological properties of powder ingredients of food raw materials, in particular nanoparticles of a food additive based on iron oxides "Magnetofood" – Fe_3O_4 (FAM).

Research subjects:

- Food grade nanoadder based on iron oxides "Magnetofood" – Fe_3O_4 (FAM);
- Highly dispersed brown or black nanopowder with a particle size of 70-80 Nm. According to the chemical composition, "Magnetofood" is a double ferum oxide ($FeO{\cdot}Fe_2O_3$ або Fe_3O_4), which was obtained by Chemical Co – deposition from aqueous solutions of two – and trivalent ferum salts in an alkaline medium (patent UA No. 126507. 53. method for obtaining the food additive "Magnetofood");
- Experimental samples of shaped jelly marmalade based on agar and pectin, which are based on basic recipes No. 11 and No. 49, respectively (see Table 1 and [31]) [29, 30]. FAM was introduced into prescription compositions in the form of an aqueous suspension during swelling-dissolution of the gelling agent in the amount of 20.0 g; 30.0 g; 40.0 g per 1000.0 g of the prescription mixture, which is equal to 0.1%; 0.15%; 0.2% of the FAM, respectively, by the mass of the prescription mixture [30]. An aqueous suspension of FAM in 5% agar and pectin Solutions was obtained by introducing FAM suspension into a 5% polysaccharide solution at a temperature of (55–60)°C with constant stirring n=(2,0–2,2) c^{-1} for (5-7)×60 C, followed by cooling the mixture to a temperature of (18–20)°C with constant stirring n=(2,0–2,2) c^{-1} [29].

Research methods

Sensory parameters

Sensory parameters (taste and smell, color, consistency, structure, shape, surface) were analyzed on a 5-point scale [29, 30]. When evaluating the smell of marmalade, attention was paid to the presence or absence of foreign, unusual odors.

Physical and chemical parameters

The total acidity and mass fraction of moisture were studied using standard and generally accepted methods [29, 30]. The acidity of experimental samples of molded jelly Marmalade was determined by titrimetric method using phenolphthalein [29]; mass fraction of moisture [30].

Table 1

Recipes for jelly shaped marmalade on agar and pectin

Raw material	Raw material consumption per 1000 g of finished products, g							
	Prototypes of jelly shaped marmalade							
	On agar				On pectin			
	Sample 1 – control	Sample 2 – experiment with 0.1% FAM	Sample 3 – experiment with 0.15% FAM	Sample 4 – experiment with 0.2% FAM	Sample 5 – control	Sample 6 – experiment with 0.1% FAM	Sample 7 – experiment with 0.15% FAM	Sample 8 – experiment with 0.2% FAM
Granulated sugar for sprinkling	86,6	86,6	86,6	86,6	86,6	86,6	86,6	86,6
Granulated sugar in jelly	525,6	524,6	524,1	523,6	718,9	717,9	717,4	716,9
Molasses	262,7	262,7	262,7	262,7	262,7	262,7	262,7	262,7
Agar	10,5	10,5	10,5	10,5	–	–	–	–
Pectin	–	–	–	–	18,0	18,0	18,0	18,0
Citric acid	11,8	11,8	11,8	11,8	12,0	12,0	12,0	12,0
Sodium lactate	–	–	–	–	10,0	10,0	10,0	10,0
Different essences	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6
Different dyes	0,5	0,5	0,5	0,5	0,6	0,6	0,6	0,6
Water suspension of FAM	–	20,0	30,0	10,0	–	20,0	30,0	10,0
Water	100,7	87,7	77,7	97,7	152,3	132,3	122,3	142,3
Output of the finished product	1000,0	1000,0	1000,0	1000,0	1000,0	1000,0	1000,0	1000,0

To simulate the storage of marmalade, a polyethylene film (HDPE, 15 microns) was used as a packaging material. Prototypes of molded jelly marmalade (thickness – 10^{-2} m, diameter – 2×10^{-2} m) 18 hours after casting and cooling were wrapped in film and stored in the dark in an air thermostat (dry-air thermostat TP-80-1) at a temperature of (18±3)°C and relative humidity φ=40-90% in increments of 10% (periodically measured relative humidity,φ%, using a hygrometer psychrometric VIT-2) for 90 days.

As a criterion for choosing a rational storage mode, we chose the constancy of the moisture content of marmalade (the moisture content of molded jelly marmalade after production is 0.179–0.181 kg/kg) [30], which depends on the humidity of the environment and the duration of storage of marmalade [29, 30]. The proposed criterion looks like this:

$$Q_{\varphi} = \sum_{i=1}^{N} |W_i - W_3| \rightarrow \min \quad (1)$$

where N – the number of tests during storage, PCs; W_3 – standard moisture content equal to 0,18 kg/kg; W_i – current moisture content, kg / kg; φ – ambient humidity,%.

Structural and mechanical properties

The strength of jelly-marmalade masses was studied by the maximum shear stress on the AR-4/1 penetrometer; rheological properties (effective viscosity) were determined on the Rheotest-2 device [29, 30].

Results and discussion

Table 2 shows the results of Sensory analysis of prototypes of molded jelly Marmalade with different gelling agents (fgar and pectin) and with different amounts of food additive based on iron oxides “Magnetofood” (FAM). This shows that the introduction of FAM in the form of an aqueous suspension at the stage of "swelling-dissolution" of the gelling agent improves the shape, surface and consistency by an average of 0.1–0.2 points (for molded jelly marmalade on agar) and 0.1–0.3 points (for molded jelly marmalade on pectin).

Table 2

Dependence of sensory parameters of experimental samples of molded jelly marmalade on agar and pectin on the mass fraction of a food additive based on iron oxides “Magnetofood” (FAM)

Replacing the indicator	Prototypes of jelly shaped marmalade			
	On agar			
	Sample 1 – control	Sample 2 – experiment with 0.1% FAM	Sample 3 – experiment with 0.15% FAM	Sample 4 – experiment with 0.2% FAM
Fragrance	5,0±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Color	5,0±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Taste	5,0±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Consistency	4,8±0,1	4,9±0,1	5,0±0,1	5,0±0,1
Shape and surface	4,8±0,1	4,9±0,1	5,0±0,1	5,0±0,1

Replacing the indicator	Prototypes of jelly shaped marmalade			
	On pectin			
	Sample 5 – control	Sample 6 – experiment with 0.1% FAM	Sample 7 – experiment with 0.15% FAM	Sample 8 – experiment with 0.2% FAM
Fragrance	5,0±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Color	5,0±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Taste	5,0±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Consistency	4,7±0,1	4,9±0,1	5,0±0,1	5,0±0,1
Shape and surface	4,8±0,1	4,9±0,1	5,0±0,1	5,0±0,1

It should be noted that the best Sensory parameters were found in samples 3, 4 (shaped jelly marmalade on agar) and samples 7, 8 (shaped jelly marmalade on pectin) with 0.15% and 0.2% FAM, respectively. Samples of marmalade had a brown-cognac color; a uniform, glassy, elastic consistency; a regular, without deformations, with a clear contour shape with a smooth, elastic and dry surface; a pleasant pronounced taste and smell characteristic of marmalade. At the same time, the rational content of FAM is 0.15% by weight of the recipe mixture. A further increase in the amount of FAM to 0.2% is impractical. Improvement of the consistency and appearance (shape, surface) of experimental samples of molded jelly marmalade is associated with the structure-forming and stabilizing effect of amphiphilic, surfactant FAM nanoparticles [29, 30].

In the production of marmalade products, the main loss of moisture occurs during casting and cooling of marmalade, which affects the quality of marmalade products. Therefore, important physical and chemical indicators of marmalade are humidity and acidity. Table 3 shows the dependence of the acidity and moisture content of prototypes of molded jelly marmalade on the mass fraction of a food additive based on iron oxides "Magnetofood" (FAM).

Hence it follows that the introduction of FAM in the amount of 0.1%; 0.15%; 0.2% by weight of the recipe mixture improves the physical and chemical parameters of prototypes of molded jelly marmalade: increases the moisture content by 1.15–1.16 times (for marmalade on agar) and by 1.13–1.14 times (for marmalade on pectin) due to the moisture–binding and moisture–retaining ability of chemically active FAM nanoparticles [29]; reduces the total acidity in 1.05–1.08 times (for agar marmalade) and 1.06–1.09 times (for pectin marmalade) due to the Amphoteric properties of FAM and sorption of acidic substances on magnetofood nanoparticles, inhibiting acid hydrolysis of the main gelling component (agar, pectin).

Table 3

Dependence of physical and chemical parameters of experimental samples of molded jelly marmalade on agar and pectin on the mass fraction of a food additive based on iron oxides "Magnetofood" (FAM)

Prototypes of molded jelly marmalade	Physical and chemical parameters of experimental samples of marmalade			
	Mass fraction of moisture, %		Total acidity, °	
	on agar	on pectin	on agar	on pectin
Sample 1-control	16,2±0,5	–	18,3±0,4	–
Sample 2-with 0.1% FAM	18,6±0,8	–	17,0±0,3	–
Sample 3-with 0.15% FAM	18,8±0,9	–	17,4±0,3	–
Sample 4-with 0.2% FAM	18,8±0,9	–	17,4±0,3	–
Sample 5-Control	–	16,6±0,6	–	18,9±0,5
Sample 6-with 0.1% FAM	–	18,8±0,8	–	17,4±0,3
Sample 7-with 0.15% FAM	–	18,9±0,9	–	17,8±0,3
Sample 8-with 0.2% FAM	–	18,9±0,9	–	17,8±0,3

At the same time, a decrease in acidity practically does not affect the process of dragle formation [29, 30].

Thus, the presence of FAM in the recipe contributes to less moisture loss when cooling products after casting the marmalade mass into the mold, stabilizes the acidity at a lower level and improves the quality indicators of molded jelly marmalade.

From the analysis of physical and chemical parameters of prototypes of molded jelly Marmalade, the rational content of FAM-0.15% by weight of the recipe mixture was established.

With a further increase in the mass fraction of FAM to 0.2%, the indicators do not change, which is due to the specific properties of nanoparticles, in particular, a large specific and chemically active surface, and the achievement of the expected result even at low concentrations [29, 30].

In order to establish the storage conditions for molded jelly Marmalade, the Q criterion was determined according to Formula (1) for experimental samples of molded jelly marmalade on agar and pectin using 0.15% FAM by weight of the recipe mixture.

This mass fraction of FAM is rational and was established by previous studies [29, 30] and the study of Sensory and physico-chemical parameters given in this paper.

The results of calculating the Q criterion for samples of molded jelly marmalade are shown in Table 4.

This shows that the use of 0.15% FAM slows down changes in the Q criterion: in experimental samples on agar, Q changes (compared to the standard value of moisture content at φ=70%) – by 1.79–3.42 times in sample 1 and 1.03–2.87 times in sample 3; in experimental samples on pectin – by 1.66–3.33 times in sample 5 and 1.00–2.90 times in sample 7.

Table 4

Criterion Q for experimental samples of molded jelly marmalade on agar and pectin at specified ambient humidity (φ=40-90%) and temperature (τ=18±2 C)

Relative humidity, φ,%	Value of the Q criterion for experimental samples of jelly marmalade			
	Sample 1-control	Sample 3 – with 0.15% FAM	Sample 5-control	Sample 7 – with 0.15% FAM
40	1,405	1,257	1,392	1,237
50	1,304	1,139	1,289	1,105
60	1,179	0,990	1,136	0,869
70	0,490	0,480	0,471	0,461
80	0,876	0,492	0,789	0,459
90	1,679	1,378	1,571	1,354

Analysis of Criterion Q establishes the lowest total value of deviation of moisture content (Wi) of prototypes of molded jelly marmalade from the standard value Wn=0.180 kg/kg – at φ=70%, which determines the optimal conditions of temperature and humidity regime during storage of molded jelly marmalade: relative humidity φ=75±2%, temperature 18±2°C.

Fig.1 shows the maximum shear stress of experimental samples of jelly-marmalade masses with a rational amount of the additive "Magnetofood" (0.15% FAM – samples 3, 7) compared to control samples (0% FAM – samples 1, 5).

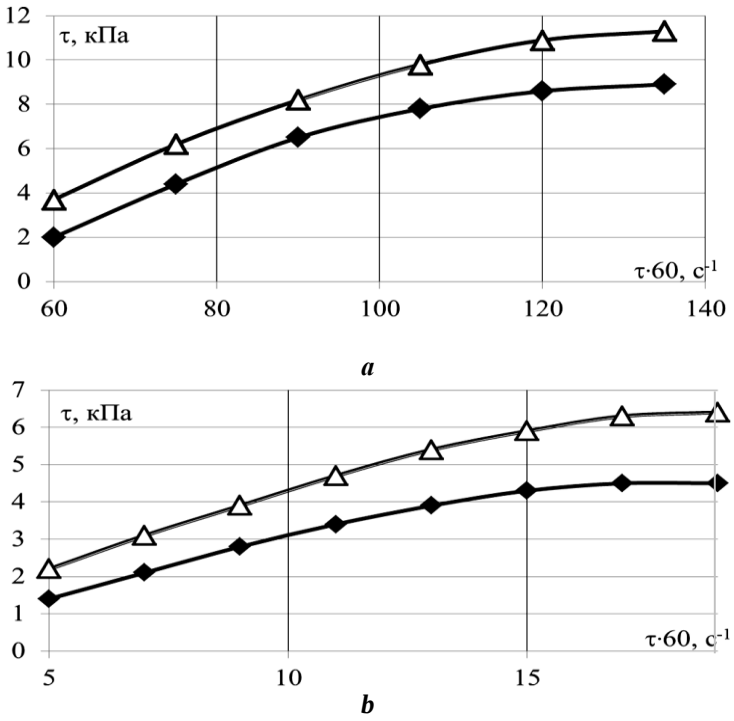

Figure 1. Maximum shear stress of samples of jelly-marmalade masses at different temperatures with different gelling agents:
***a* – on agar; *b* – on pectin**
– control samples – without FAM;
– samples with 0.15% FAM

From Figure 1 it can be seen that the introduction of FAM increases the strength of jelly-marmalade jelly by 1.3–1.5 times (for agar marmalade) and by 1.22–1.4 times (for pectin marmalade). This is due to the ability of nanowires of the Magnetofood additive to interact with polysaccharide molecules, which forms an ordered spatial framework that strengthens gel-like structures. As a result, a beautiful texture of molded jelly marmalade is formed, which gives it high consumer properties and extends the period of preserving its freshness, in particular, the release of moisture during storage is significantly reduced.

Thus, studies of the structural and mechanical properties of jelly-marmalade masses with various gelling agents confirm the hypothesis of stabilization of the dispersed structure by FAM nanoparticles. In addition, the introduction of FAM molded jelly marmalade in the amount of 0.15% by weight of the recipe mixture at the stage of "swelling-dissolution" of the gelling agent reduces the amount of agar by (9–11)% and pectin by (7–9)% and increases the strength of jelly-marmalade jelly by (10±1)% for agar and (8±1)% for pectin.

The conducted studies indicate a complex effect of food nanoadditives based on double oxide of divalent iron “Magnetofood” (FAM) due to its structure – forming and stabilizing abilities, which in the technologies of jelly-marmalade production can improve the functional and technological properties of colloidal dispersed systems.

Conclusions

The ability of nanoparticles of the food additive Fe_3O_4 "Magnetofood" to contribute compared to the control was noted:

1. Improvement of Sensory parameters of shaped jelly marmalade: the shape, surface and consistency improves by 0.1–0.2 points (for agar marmalade) and by 0.1-0.3 points (for pectin marmalade).
2. An increase in the moisture content by 1.15–1.16 times in experimental samples on agar and by 1.13–1.14 times in experimental samples on pectin-due to the moisture-binding and moisture-retaining ability of chemically active nanoparticles of the additive "Magnetofood". In addition, the total acidity decreases by 1.05–1.08 times in experimental samples on agar and by 1.06–1.09 times in experimental samples on pectin-due to the Amphoteric nature of the Magnetofood additive and its ability to interact with acidic substances of jelly-marmalade masses;
3. The positive effect of introducing the food additive "Magnetofood" in the amount of 0.10–0.20 WT is proved.% on the structural and mechanical properties of molded jelly marmalade: increases the strength of jelly-marmalade jelly by 1.3–1.5 times (for marmalade on agar) and 1.22–1.4 times (for marmalade on pectin) due to the structure-forming and stabilizing action of nanoparticles "Magnetofood", which contributes to the formation of an ordered spatial framework, which strengthens gel-like structures.
4. The rational content of the food additive "Magnetofood" is determined – 0.15% by weight of the recipe mixture for both gelling agents (agar and pectin).
5. Optimal conditions of temperature and humidity regime during storage of molded jelly marmalade are established: relative humidity φ=(75±2)%, temperature (18±2)°C, recommended storage duration of 90 days.

The conducted studies indicate a complex effect (water – retaining, structure-forming and stabilizing a

bility) of food nano-additives based on double oxide of two-and trivalent iron "Magnetofood" (FAM), which in the technologies of jelly-marmalade products can improve the functional and technological properties of colloidal dispersed systems, improve the quality and extend the time of preserving the freshness of finished products.

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Анотації

Харчові технології

Вплив періодичних умов мікрохвильового висушування на характеристики та фізичні властивості буряків

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Вступ. Мета цього дослідження – дослідити вплив періодичних умов мікрохвильового висушування (коефіцієнт імпульсів мікрохвиль, щільність потужності мікрохвиль та товщина зрізів) на характеристики сушіння та фізичні властивості буряків.

Матеріали та методи. Характеристики сушіння та фізичні властивості буряків досліджували з використанням періодичної мікрохвильової сушки при різних коефіцієнтах імпульсів мікрохвиль (1, 2, 3 та 4), щільності потужності мікрохвиль (1,0, 1,5, 2,0 та 2,5 Вт/г) та товщині зрізів (2, 4, 6 та 8 мм). Аналізатор вологи та переносний вимірювач активності води використовувались для визначення вологості та водної активності буряків відповідно. Метод зважування був використаний для оцінки регідратаційної здатності висушених буряків. Для оцінки якості кольору буряка використовували колориметр.

Результати і обговорення. Результати показали, що відношення вологи постійно зменшувалось із збільшенням часу сушіння на всіх обробних процедурах. За винятком щільності потужності мікрохвильової печі 2,5 Вт/г, всі умови сушіння мали короткий період нагрівання (прогрівання), період сушіння з приблизно постійною швидкістю та період сушіння з падінням. Тим часом час сушіння зменшувався із збільшенням щільності потужності мікрохвиль, в той час як значно збільшувався із зростанням коефіцієнта мікрохвильових імпульсів та товщини зрізу. Не було значної різниці в кінцевій вологості та водної активності висушених буряків під час усіх процедур сушіння. Коефіцієнт регідратації зменшувався із збільшенням товщини зрізу (від 2 до 8 мм), щільності потужності НВЧ (від 1,5 до 2,5 Вт/г) та коефіцієнта імпульсів мікрохвиль (від 2 до 4). Порівняно зі свіжими буряковими, усі бурякові після переривчастого мікрохвильового сушіння мали нижчі значення *a* та *C*, а також більш високі значення *L*.

Висновки. Беручи до уваги характеристики сушіння та фізичні властивості буряків та споживання енергії, оптимальними умовами переривчастої сушіння мікрохвиль для свіжих буряків є коефіцієнт мікрохвильового імпульсу 2, щільність потужності НВЧ 2,0 Вт/г, і товщина скибочки 2 мм.

Ключові слова: *бурякові, сушіння, ПНЧ-випромінювання, регідратація.*

Дослідження поєднання борошна з гарбузового насіння та м'яса індички в шинках

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Вступ. Проведено дослідження для визначення ефекту поєднання борошна з гарбузового насіння та м'яса індички в шинках.

Матеріали і методи. Досліджена технологія шинок з використанням математичного моделювання та результат додавання до їх складу борошна з гарбузового насіння та м'яса індички. Визначення амінокислотного складу проводили за допомогою методу іонообмінної хроматографії

Результати і обговорення. Частка м'язової тканини в тушках індиків 1 -го і 2 -го сортів знаходиться в межах 44–47% і є домінуючою, вміст шкіри з підшкірним жиром – 13–22%.

Визначено, що вміст білка в олійних культурах не відрізняється від м'ясної сировини, і їх можна вважати хорошим джерелом рослинного білка (19,4-34,2%).

Аналіз амінокислотного складу білків олійних культур показав, що вони містять усі незамінні амінокислоти, але є незначні відмінності в їх кількісному складі. В олійних культурах переважною амінокислотою є лейцин для насіння кунжуту, лейцин і валін для насіння соняшнику, фенілалін для насіння гарбуза.

Розроблено три експериментальні рецепти реструктурованої шинки із заміною м'яса індички шкіркою індички в кількості 10% та борошна з гарбузового насіння у кількості 5, 10, 15%, гідратованої у співвідношенні 1:2.

Фізико-хімічні дослідження показали, що шинка, виготовлена із шкірки індички та борошна з гарбузового насіння, має вищий вміст білка та більш збалансоване співвідношення білка та жиру за співвідношенням 1:1, відповідно до ідеального харчування,

Висновки. Встановлено високу якість трьох рецептур, розроблених і випробуваних на виробництві реструктурованих шинок, в яких поєднано 10% шкірки індички та 5–15% борошна з гарбузового насіння.

Ключові слова: *м'ясо, птиця, гарбуз, борошно, шинка.*

Рейтинг якості десертів на основі плодово-ягідної сировини

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Вступ. Метою дослідження є вивчення рейтингу якості десертів на основі плодово-ягідного купажного напівфабрикату з підвищеною антиоксидантною здатністю та покращеними органолептичними показниками.

Матеріали і методи. Плодово-ягідний купажний напівфабрикат на основі яблука і банана. Методи дослідження: експертний метод оцінок; рейтинговий метод із 20 дескрипторів портретів профілю флейвору; профільний метод за 10 бальною шкалою відповідності інтенсивностей відчуття ароматичних і смакових властивостей; редоксметрія – визначення антиоксидантної здатності; *pH*-метрія.

Результати. У статті наведені результати впливу вирішальних чинників для

формування якісних характеристик інноваційних десертів (типу самбук). Проведено аналіз системного підходу на підвищення якості продукції. Розроблено модель технологічної системи. Дано пояснення значень кожної підсистеми, її складових і функцій.

Оцінку показників якості десертів визначено шляхом отримання середнього значення окремих дескрипторів. Органолептичні характеристики інноваційного десерту: однорідна напівгуста консистенція; колір відповідає плодово-ягідної сировині, рівномірний по всій поверхні; смак і запах чисті. На основі отриманих результатів розраховано рейтинг інноваційного десертів. Зразок десерту «Яблуко-банан» має вищий рейтинговий показник – 96.815 балів порівняно з контрольним зразком «Яблуко» – 91.195 бала, який має значення, що на 5.8% більше, ніж контроль.

Було отримано мінімальне теоретичне значення окисно-відновного потенціалу (ОВП) для водно-спиртових настоїв, яке має значення (Eh_{min}) від 277.2 мВ («Яблуко-банан») до 412.8 мВ («Яблуко»). Встановлено фактичне виміряне значення ОВП настоїв (Eh_{act}) – від 126 мВ («Яблуко-банан») до 318 мВ («Яблуко»). Водневий показник для водно-спиртових настоїв має значення від 4.12 од. pH («Яблуко») до 6.38 од. pH («Яблуко-банан»). Водно-спиртові настої з рослинної сировини мають значення відновної здатності (енергія відновлення – ЕВ) в діапазоні від ЕВ – 94.8 мВ («Яблуко») до ЕВ – 151.2 мВ («Яблуко-банан»). Для ресторанного бізнесу у виробництві десертів перспективною є яблучно-бананова композиція, яка отримала підвищені антиоксидантні характеристики.

Висновки. Обґрунтовано використання плодово-ягідної сировини для розширення показників якості десертів за допомогою методу комплексного критерію якості та розрахунку рейтингу десертів.

Ключові слова: *десерт, купаж, напівфабрикат, якість, рейтинг.*

Обґрунтування вибору плодово-ягідної сировини для підвищення харчової цінності кондитерських виробів

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Вступ. Метою дослідження є обґрунтування вибору плодово-ягідної сировини з високим вмістом біологічно активних речовин та отримання композиції на її основі для підвищення харчової цінності кондитерських виробів.

Матеріали і методи. Досліджена як традиційна, так і нетрадиційна плодово-ягідна сировина для виробництва мармеладу: яблука, сливи, вишні, смородина чорна, смородина червона, чорниця, журавлина, ожина, терен, калина, інжир, аґрус, дереза, бузина, черемха та фізаліс.За загальновідомими методиками у кожному виді сировини визначено вміст органічних кислот та пектинових речовин, як важливих і визначальних для мармеладного виробництва так і вміст біофлавоноїдів, аскорбінової кислоти, каротиноїдів, клітковини, необхідних для надання готовому виробу оздоровчих властивостей.

Результати і обговорення. Доцільним є не тільки розширення сировинної бази пюре, а й створення купажних композицій пюре для мармеладу з метою підвищення

харчової цінності виробу, надання йому оздоровчих властивостей та створення конкурентоспроможної продукції на ринку.

За встановленим вмістом основних біокомпонентів дослідженої культивованої та дикорослої сировини були обрані наступні плоди та ягоди: слива, черемха та чорна смородина.

Вміст біофлавоноїдів, каротиноїдів та аскорбінової кислоти один з найвищих серед досліджених зразків у обраних ягодах чорної смородини та черемхи, за одночасно високого вмісту пектинових речовин 1,1%, клітковини та органічних кислот. При цьому сливу було обрано, як значне джерело пектинових речовин та органічних кислот, що є важливо необхідними для драглеутворення.

У складі готового мармеладу використання обраної композиції плодово-ягідного пюре у кількості 25–30% дозволяє збагатити його значною кількістю біологічно активних речовин, вміст яких у традиційному виробі є незначним.

Висновки. Результати показали доцільність залучення при виробництві продукції оздоровчого спрямування плодово-ягідної сировини в тому числі і нетрадиційної дикорослої.

Ключові слова: *мармелад, черемха, смородина, слива, біофлавоноїди.*

Функціонально-технологічні властивості харчової нанодобавки на основі подвійного оксиду дво- та тривалентного заліза у виробництві формового желейного мармеладу

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Вступ. Досліджено функціонально-технологічні властивостей харчової нанодобавки на основі подвійного оксиду дво- та тривалентного заліза “Магнетофуд”(Fe_3O_4) у виробництві формового желейного мармеладу.

Матеріали та методи. Дослідні зразки формового желейного мармеладу на агарі й пектині. Функціонально-технологічні властивості досліджували за допомогою органолептичних (смак, запах, колір, консистенція, форма та поверхня – за 5-ти бальною шкалою); фізико-хімічних (масова частка вологі, загальна кислотність, що визначали гравіметричним та титриметричним методами відповідно); структурно-механічних методів. Міцність мармеладного студню визначали за граничною напругою зсуву на пенетрометрі АР-4/1.

Результати і обговорення. Відзначено здатність наночастинок харчової добавки Fe_3O_4 “Магнетофуд” сприяти: покращенню органолептичних показників формового желейного мармеладу: форма, поверхня та консистенція покращується на 0,1–0,2 бали (для мармеладу на агарі) та на 0,1–0,3 бали (для мармеладу на пектині); збільшенню вмісту вологи в 1,15–1,16 рази в дослідних зразках на агарі та в 1,13–1,14 рази в дослідних зразках на пектині за рахунок вологозв’язувальної та вологоутримувальної здатності хімічно активних наночастинок добавки “Магнетофуд”; зменшенню загальної кислотності в 1,05–1,08 рази в дослідних зразках на агарі та в 1,06–1,09 рази в дослідних зразках на пектині за рахунок амфотерних та сорбційних властивостей добавки.

Встановлено підвищення міцності желейно-мармеладного студню в 1,3–1,5 рази (для мармеладу на агарі) та в 1,22–1,4 рази (для мармеладу на пектині) при внесенні 0,1–0,2% “Магнетофуд” за рахунок структуроутворювальної та стабілізувальної дії наночастинок добавки. Визначено раціональний вміст харчової добавки “Магнетофуд” – 0,15% від маси рецептурної суміші для обох гелеутворювачів (агару й пектину).

Встановлено оптимальні умови температурно-вологістного режиму під час зберігання формового желейного мармеладу: відносна вологість повітря φ=(75±2)%, температура (18±2)°С, рекомендована тривалість зберігання 90 діб.

Висновки. Вперше досліджено функціонально-технологічні властивості харчової нанодобавки на основі подвійного оксиду дво- та тривалентного заліза у виробництві формового желейного мармеладу.

Ключові слова: *мармелад, наночастинки, Fe_3O_4, функціональність.*

Instructions for Authors

Dear colleagues!

The Editorial Board of scientific periodical «**Ukrainian Journal of Food Science**» invites you to publication of your scientific research.

Requirements for article:
Language – English
Size of the article 10 – 20 pages.
All article elements should be in Times New Roman, font size 14, 1 line intervals, margins on both sides 2 cm.

The structure of the article:

1. The title of the article
2. Authors (full name and surname)
3. Institution, where the work performed.
4. Abstract. The structure of the Abstract should correspond to the structure of the article (Introduction, Materials and methods, Results and discussion, Conclusion)
5. Key words.
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   - Materials and methods
   - Results and discussion
   - Conclusion
   - References

   If you need you can add another parts and divide them into subparts.
7. The information about the author (Name, surname, scientific degree, place of work, email and contact phone number).

All Figure s should be made in graphic editor, the font size 14.

The background of the graphs and charts should be only in white colour. The colour of the Figure elements (lines, grid, text) – in black colour.
Figure s and EXCEL format files with graphs additionally should submit in separate files.

Photos are not appropriate to use.

Extended articles should be sent by email to:
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Ukrainian Journal of Food Science публікує оригінальні наукові статті, короткі повідомлення, оглядові статті, новини та огляди літератури.

Тематика публікацій в **Ukrainian Journal of Food Science:**

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Процеси та обладнання
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Періодичність журналу 2 номери на рік (червень, грудень).

Результати досліджень, представлені в журналі, повинні бути новими, мати зв'язок з харчовою наукою і представляти інтерес для міжнародного наукового співтовариства.

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Рецензія рукопису статті. Наукові статті, представлені для публікації в «**Ukrainian Journal of Food Science**» проходять «подвійне сліпе рецензування» (рецензент не знає, чию статтю рецензує, і, відповідно, автор не знає рецензента) двома вченими, призначеними редакційною колегією: один є членом редколегії, інший – незалежний учений.

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Редакційна колегія наукового періодичного видання
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Вимоги до оформлення статей

Мова статей – англійська.

Мінімальний обсяг статті – **10 сторінок** формату А4 (без врахування анотацій і списку літератури)**.**

Для всіх елементів статті шрифт – **Times New Roman**, кегль – **14**, інтервал – 1.

Всі поля сторінки – по 2 см.

Структура статті:

1**.** УДК**.**
2. **Назва статті.**
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4. *Установа, в якій виконана робота*.
5. Анотація. **Обов'язкова** структура анотації:
   - Вступ (2–3 рядки).
   - Матеріали та методи (до 5 рядків)
   - Результати та обговорення (пів сторінки).
   - Висновки (2–3 рядки).
6. Ключові слова (3–5 слів, але не словосполучень).

Пункти 2–6 виконати англійською і українською мовами.

7. Основний текст статті. Має включати такі обов'язкові розділи:
   - Вступ
   - Матеріали та методи
   - Результати та обговорення
   - Висновки
   - Література.

За необхідності можна додавати інші розділи та розбивати їх на підрозділи.

8. Авторська довідка (Прізвище, ім'я та по батькові, вчений ступінь та звання, місце роботи, електронна адреса або телефон).
9. Контактні дані автора, до якого за необхідності буде звертатись редакція журналу.

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Фон графіків, діаграм – лише білий. Колір елементів рисунку (лінії, сітка, текст) – чорний (не сірий).

Рисунки та графіки EXCEL з графіками додатково подаються в окремих файлах.

Скорочені назви фізичних величин в тексті та на графіках позначаються латинськими літерами відповідно до системи СІ.

У списку літератури повинні переважати англомовні статті та монографії, які опубліковані після 2010 року.

Оформлення цитат у тексті статті:

Кількість авторів статті	Приклад цитування у тексті
1 автор	(Arych, 2019)
2 і більше авторів	(Bazopol et al., 2021)

Приклад тексту із цитуванням: It is known (Bazopol et al., 2006; Kuievda, 2020), the product yield depends on temperature, but, there are some exceptions (Arych, 2019).

У цитуваннях необхідно вказувати одне джерело, звідки взято інформацію.
Список літератури сортується за алфавітом, літературні джерела не нумеруються.

Правила оформлення списку літератури

В Ukrainian Food Journalвзято за основу загальноприйняте в світі спрощене оформлення списку літератури згідно стандарту Garvard. Всі елементи посилання розділяються **лише комами**.

1. Посилання на статтю:

Автори А.А. (рік видання), Назва статті, *Назва журналу (курсивом)*, Том (номер), сторінки.

Ініціали пишуться після прізвища.
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1. Приклад:
Popovici C., Gitin L., Alexe P. (2013), Characterization of walnut (Juglans regia L.) green husk extract obtained by supercritical carbon dioxide fluid extraction, *Journal of Food and Packaging Science, Technique and Technologies,* 2(2), pp. 104–108.

2. Посилання на книгу:

Автори (рік), *Назва книги (курсивом)*, Видавництво, Місто.

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Всі елементи посилання розділяються комами.
Приклад:

2. Wen-Ching Yang (2003), *Handbook of fluidization and fluid-particle systems*, Marcel Dekker, New York.

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Приклади:

(2013), *Svitovi naukovometrychni bazy*, Available at: http://www.nas.gov.ua/publications/q_a /Pages/scopus.aspx

Cheung T. (2011), *World's 50 most delicious drinks*, Available at: http://travel.cnn.com/explorations/drink/worlds–50-most-delicious-drinks–883542

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