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Chemical, rheological, and sensory properties of wheat biscuits fortified with local buckwheat

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Abstract:
The research featured two species of buckwheat: *Fagopyrum esculentum* Moench. and *Fagopyrum tataricum* (L.) Gaertn.
The authors used 10, 20, or 30% of buckwheat flour to substitute soft wheat flour in order to obtain biscuits with improved sensory and nutritional properties.
The biscuits were tested for chemical composition, rheology, color, baking quality, sensory properties, and texture. The sample made of soft wheat flour and *F. tataricum* contained less protein and fat than the sample with *F. esculentum*. The samples with *F. tataricum* demonstrated greater amounts of fiber and ash while the samples made of soft wheat flour were rich in carbohydrates. The additional increment enhanced the arrival time, dough development time, dough stability, the mixing tolerance index, and weakening. Compared to the control, the samples with *F. esculentum* demonstrated lower peak, trough, breakdown, final, and setback viscosities. *F. tataricum*, on the contrary, increased the viscosity readings. The biscuits fortified with *F. esculentum* and *F. tataricum* contained more protein, fat, ash, and crude fiber the control. The control biscuits also exceeded the total carbohydrates. The experimental biscuits with *F. esculentum* and *F. tataricum* were darker in color than the control: the lightness (L^*) and redness values (b^*) decreased as the proportion of *F. esculentum*/*F. tataricum* rose. However, the experimental biscuits had a higher level of yellowness (a^*). As the replacement levels rose, *F. esculentum* and *F. tataricum* reduced biscuit weight and volume.
According to the research results, 30% *F. esculentum* and 20% *F. tataricum* proved able to yield nutritious biscuits with outstanding physical properties. Greater proportions of *F. esculentum*/*F. tataricum* resulted in poor sensory ratings for color, taste, flavour, texture, appearance, and overall acceptability.

Keywords: *Fagopyrum tataricum*, *Fagopyrum esculentum*, semolina, biscuit, chemical composition, color, baking quality, sensory evaluation, texture

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INTRODUCTION

Cereals products constitute an essential part of human diet. They are responsible for carbohydrates, proteins, fats, dietary fiber, B-group vitamins, and minerals. Whole grains are an essential ingredient in many processed foods [1]. In Egypt, biscuits are a popular bakery item consumed by nearly all social groups. They are affordable, nutritious, shelf-stable, and diverse in shape and taste. Bakery products are often fortified with various nutritional ingredients [2–4]. A basic biscuit formulation includes such essential primary ingredients as flour, fats, water, and sugar. Fats provide plasticity and incorporate air during dough formation. They enable the dough to withstand the baking temperatures without losing shape [5].

Buckwheat is a so-called pseudocereal that derives from the genus of *Fagopyrum*. The common buckwheat (*Fagopyrum esculentum* Moench.) is the most prevalent buckwheat species [6]. Buckwheat is highly adaptable and thrives in various conditions [7]. It contains such flavonoids as quercetin, vitexin, orientin, isovitexin, and

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isoorientin. The flavonoid content depends on numerous factors, e.g., testa, seed size and shape, flower color, seeding time, soil placement, environment, climate, growth phases, region, etc. [8]. Buckwheat seeds are also abundant in dietary fibre, which has a beneficial physiological effect on the gastrointestinal system and facilitates the metabolism of other nutrients [9]. In addition, buckwheat seeds are gluten-free and suitable for people with celiac disease [10]. Buckwheat flour is a highly nutritional component often used in pasta, noodles, pancakes, bread, biscuits, etc. [11]. The research objective was to develop a new biscuit formulation from different combinations of the common buckwheat (*F. esculentum*) and the green, or Tatar, buckwheat (*Fagopyrum tataricum* (L.) Gaertn.), as well as to determine the effect of processing procedures on the chemistry, rheology, color, backing quality, sensory properties, and texture of the finished product.

STUDY OBJECTS AND METHODS

This research involved *Fagopyrum esculentum* Moench. (California) and *Fagopyrum tataricum* (L.) Gaertn. (Hong Kong) seeds. The samples possessed a state-certified identification label that provided the scientific, local, and English names of the species, as well as some data on germination and purity ratios. The seeds were sowed, planted, and harvested in the city of Belbies (Sharkia governorate, Egypt; coordinates: 30.4196° N, 31.5619° E) and the city of Sadat (Monofiya, Egypt; coordinates: 30.3594° N, 30.5327° E) in 2018–2019 and 2019–2020 to evaluate the growth and quality of the buckwheat at various growing times. This research involved only hand-picked grains. After initial drying in the field for 3–4 days, they were put in a clean, shaded place for further drying and kernel separation. The soft wheat flour was supplied by South Cairo Mill Company (Giza, Egypt) and accounted for 72% of the total weight. Sugar, eggs, salt (sodium chloride), shortening, baking powder, and vanilla were purchased at a local market (Giza, Egypt).

The list of analytical reagent-grade chemicals and solvents included trichloroacetic acid, thiobarbituric acid, and DPPH (2,2-Diphenyl-1-picryl-hydrazyl). They were obtained from El-Gomhouria Co. for Trading Drugs, Chemicals, and Medical Supplies (Cairo, Egypt).

Technological treatment. ***Preparing the flour mixes.*** *F. esculentum* and *F. tataricum* grains were cleaned, tempered (15% moisture), milled (Quadrumat Junior flour mill), filtered through a 40-mesh screen, and packaged in plastic bags. The blends of soft wheat flour (72% extraction) with *F. esculentum* and *F. tataricum* flour had the following ratios: 100:0, 90:10, 80:20, and 70:30 w/w.

Rheology of dough. The farinograph and rapid-visco-analyzer tests followed the guidelines developed by the American Association of Cereal Chemists to determine the rheological qualities of the samples [12].

Preparing the biscuits. We mixed 200 g of soft wheat flour with 10, 20 and 30% of *F. esculentum* or *F. tataricum*. The biscuits were cooked according to the formulation recommended by The Association of Official Analytical Chemists with some modifications (Table 1) [13]. The dry ingredients (flour, sugar, salt, and baking powder) were thoroughly mixed in a bowl by hand for 3 min. Then, egg was added and kneaded in. The dough was rolled and sliced with a five-millimeter biscuit cutter. The biscuits were baked on trays at 200°C for 25 min. After that, they were cooled, packaged in plastic bags, and stored at 28 ± 2°C before the analytical and sensory assessment.

Baking quality. The weight, volume, specific volume, diameter, thickness, and spread ratio were measured in triplicates.

Color attributes. The color of both mixes and biscuits were measured using a Spectro-Colorimeter (Tristimulus Color Machine) with a CIE lab color scale (Hunter, Lab Scan XE, Reston VA.) calibrated using a white Hunter Lab color standard tile (LXNO. 16379): X = 77.26, Y = 81.94, and Z = 88.14. The Hunter-Scotfield's equation was used to measure the color difference (E) using Hunter a, b, and L scales:

$$\Delta E = (\Delta a^2 + \Delta b^2 + \Delta L^2)1/2,$$
$$a = a - a_0,\ b = b - b_0,\ L = L - L_0$$

where 0 stood for the control color.

The hue angle and saturation index were calculated in line with the procedure described by Sapers & Douglas [14].

Table 1 Biscuit formulation

Samples	Control	*Fagopyrum esculentum*			*Fagopyrum tataricum*		
		10%	20%	30%	10%	20%	30%
		Buckwheat biscuit formulation					
Soft wheat flour	100	90	80	70	90	80	70
Buckwheat flour	–	10	20	30	10	20	30
Salt	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Sucrose	35	35	35	35	35	35	35
Shortening	28	28	28	28	28	28	28
Egg	30	30	30	30	30	30	30
Baking powder	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Vanilla	1	1	1	1	1	1	1

Sensory evaluation. The sensory evaluation relied on the method developed by Hussein *et al.* [15]. Each formulation was analyzed by twenty panelists. Each panelist gave the product a score between 0 and 20 based on its color, smell, taste, texture, appearance, and general acceptability.

Texture analysis. The biscuit samples underwent a texture analysis using a texturometer (Brookfield, CT3-10 kg, USA) with a cylinder probe (TA. AACC36). The hardness, stickiness, resilience, cohesion, springiness, gumminess, and chewiness were measured using the method of texture profile analysis, which was programmed for two cycles of measurements to generate a two-bit texture profile curve. The trigger load was 9.00 N g, and the test speed was 2.5 mm/s.

Analytical methods. ***Chemical composition.*** The ash, crude fiber, fat, and protein levels were calculated using the standards developed by The Association of Official Analytical Chemists [13]. The carbohydrate content was determined as follows:

$$\text{Carbohydrates} = 100 - (\%\ \text{protein} + \%\ \text{fat} + \\ + \%\ \text{ash} + \%\ \text{crude fiber})$$

Statistical analysis. The obtained results were evaluated statistically using the analysis of variance reported by McClave & Benson [16].

RESULTS AND DISCUSSION

Chemical composition of raw materials. The soft wheat flour, *Fagopyrum tataricum* (L.) Gaertn., and *Fagopyrum esculentum* Moench. were analyzed for moisture, ash, crude protein, lipid, crude fiber, and carbohydrates. Table 2 displays the acquired values for the chemical composition of soft wheat flour, *F. tataricum*, and *F. esculentum*. The soft wheat flour had the most effective moisture content (11.65%), followed by *F. esculentum* (9.17%) and *F. tataricum* (8.78%). *F. esculentum* had higher protein and fat concentrations (14.90 and 2.18%) than soft wheat flour (11.81 and 1.57%) and *F. tataricum* (11.32 and 1.66%). *F. tataricum* contained more fiber and ash than *F. esculentum* (12.51 and and 2.58%) and soft wheat flour (0.79 and 0.81%), respectively (22.08 and 2.85%). Soft wheat flour had a more significant proportion of total carbohydrates than *F. tataricum* and *F. esculentum*. The results obtained were consistent with those published elsewhere [17–21].

Rheological parameters. ***Farinograph parameters.*** Table 3 and Fig. 1 illustrate the effects of 10, 20, and 30% *F. esculentum*/*F. tataricum* on the farinograph test parameters. The findings demonstrated the effect of combining *F. esculentum*/*F. tataricum* at 10, 20, and 30% with soft wheat flour on such farinograph parameters as water absorption, arrival time, dough development time, dough stability, and dough deterioration. The water absorption value of the soft wheat flour sample was 61.2%. Its combinations with different proportions of *F. esculentum*/*F. tataricum* resulted both in a progressive decline and an increase. In tandem with the extra increase, the arrival time, dough development time, dough stability, mixing tolerance index, and weakening went down, compared to the control. The increased dough development time and stability may have been

Table 2 Proximate chemical composition of raw materials, %

Samples	Chemical composition					
	Moisture	Ash	Fiber	Protein	Lipids	Total carbohydrates
Soft wheat flour	11.65 ± 0.25	0.81 ± 0.10	0.79 ± 0.09	11.32 ± 0.11	1.66 ± 0.14	85.37 ± 0.31
Fagopyrum esculentum	9.17 ± 0.17	2.58 ± 0.07	12.51 ± 0.32	14.90 ± 0.27	2.18 ± 0.05	59.08 ± 0.56
Fagopyrum tataricum	8.78 ± 0.29	2.85 ± 0.01	22.08 ± 0.37	11.81 ± 0.25	1.57 ± 0.03	52.60 ± 0.85

Table 3 Effect of *Fagopyrum esculentum*/*Fagopyrum tataricum* on farinograph parameters

Samples	Water absorption, %	Arrival time, min	Dough development time, min	Dough stability, min	Mixing tolerance Index, Brabender unit	Weakening, Brabender unit
Control (100% soft wheat flour)	61.2	1.5	1.5	3.5	60	90
10% *Fagopyrum esculentum* + 90% soft wheat flour	60.8	1.0	1.5	6.0	40	80
20% *Fagopyrum esculentum* + 80% soft wheat flour	60.6	1.5	2.5	6.5	50	90
30% *Fagopyrum esculentum* + 70% soft wheat flour	60.4	2.0	5.0	8.5	70	70
10% *Fagopyrum tataricum* + 90% soft wheat flour	61.0	1.0	1.5	3.0	60	100
20% *Fagopyrum tataricum* + 80% soft wheat flour	61.2	1.5	3.0	5.5	80	110
30% *Fagopyrum tataricum* + 70% soft wheat flour	61.8	2.0	3.5	5.0	100	120

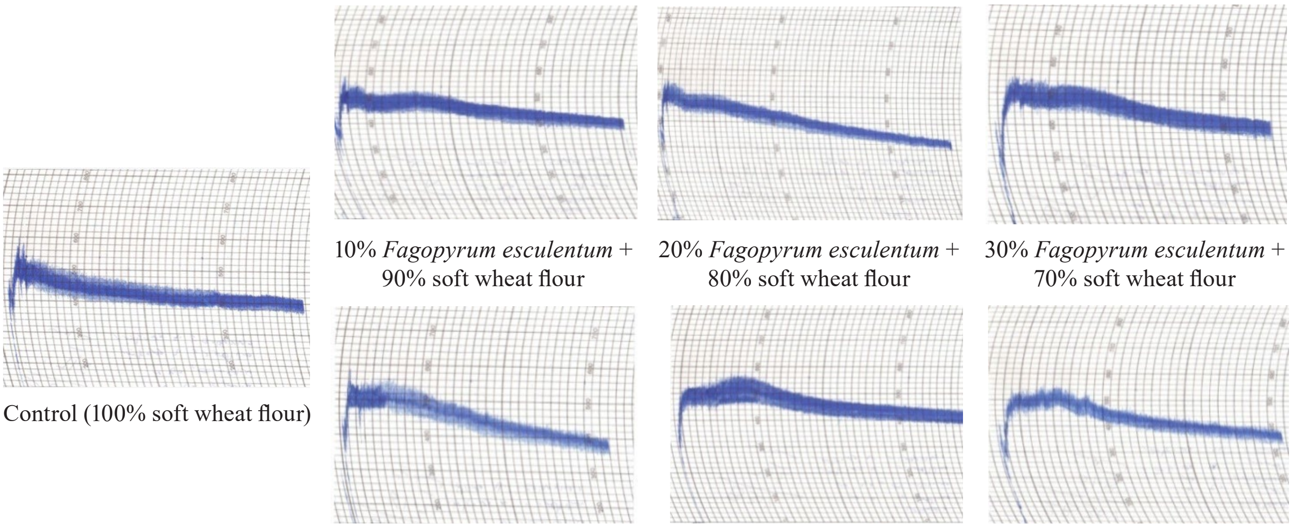


Figure 1 Farinograph parameters of dough samples with 10, 20, and 30% *Fagopyrum esculentum*/*Fagopyrum tataricum*

Table 4 Effect of *Fagopyrum esculentum*/*Fagopyrum tataricum* on pasting properties

Samples	Peak viscosity, cP	Trough viscosity, cP	Break down viscosity, cP	Final viscosity, cP	Setback viscosity, cP	Peak time, min	Pasting temperature, °C	Peak temperature, °C
Control (100% soft wheat flour)	2508	1659.92	977.8	2573	–64.92	12.1	42.4	94.5
10% *Fagopyrum esculentum* + 90% soft wheat flour	3008	1452.7	1555	2648	359.7	9.67	64.8	94.8
20% *Fagopyrum esculentum* + 80% soft wheat flour	1869	1070.58	798	1863	5.58	9.4	66.1	94.6
30% *Fagopyrum esculentum* + 70% soft wheat flour	2528	1521.52	1139	2595	66.52	9.23	63.5	94.6
10% *Fagopyrum tataricum* + 90% soft wheat flour	3671	1463.6	2208	2946	724.8	9.9	64.3	94.4
20% *Fagopyrum tataricum* + 80% soft wheat flour	3445	1421.7	2023	2910	535.2	9.9	64.3	94.6
30% *Fagopyrum tataricum* + 70% soft wheat flour	3022	1707.9	1613	2838	183.9	9.97	63.6	94.6

induced by a slower water hydration rate and gluten formation due to the increased fiber content. The higher mixing tolerance and extension value might have resulted from the interactions between gluten and fiber [3]. As gluten diluted in the flour samples, it could not interact with starch, thus resulting in a greater mixing tolerance index [22, 23].

Pasting profile. Table 4 and Fig. 2 demonstrate the pasting properties of the flour mixes. The control sample with soft wheat flour showed the following pasting viscosities: peak viscosity – 2508 cP, trough viscosity – 1659.92 cP, breakdown viscosity – 977.8 cP, final viscosity – 2573 cP, setback viscosity – 64.92 cP. The sample with *F. esculentum* reduced the peak, trough, breakdown, final, and setback viscosities of soft wheat flour from 2508 to 1869 cP, 1659.92 to 1070.58 cP, 977.8 to 798 cP, and 2573 to 1863 cP, respectively. In contrast, the samples with *F. tataricum* enhanced all the viscosity parameters: peak viscosity – 3022 cP, trough viscosity – 1707.9 cP, breakdown viscosity – 1613 cP, final viscosity – 2838 cP, setback viscosity – 183.9 cP. The thermal data for both *F. esculentum* and *F. tataricum* samples were as follows: peak time – 9.23–9.97 min, pasting temperature – 66.1–63.5°C, peak temperature – 94.6–94.8°C. According to Hallen *et al.*, the degradation of the pasting profile might occur as a result of the fact that less starch is available for gelatinization [24]. Symons & Brennan reported similar findings [25]. They replaced wheat starch with 5% barley b-glucan fiber fractions, and the peak viscosity went down because less starch was available for gelatinization and less water was available for the first swelling of the starch granule. Adebowale *et al.* linked the pasting temperature with the water-binding capacity [26]. In other studies [24, 27],

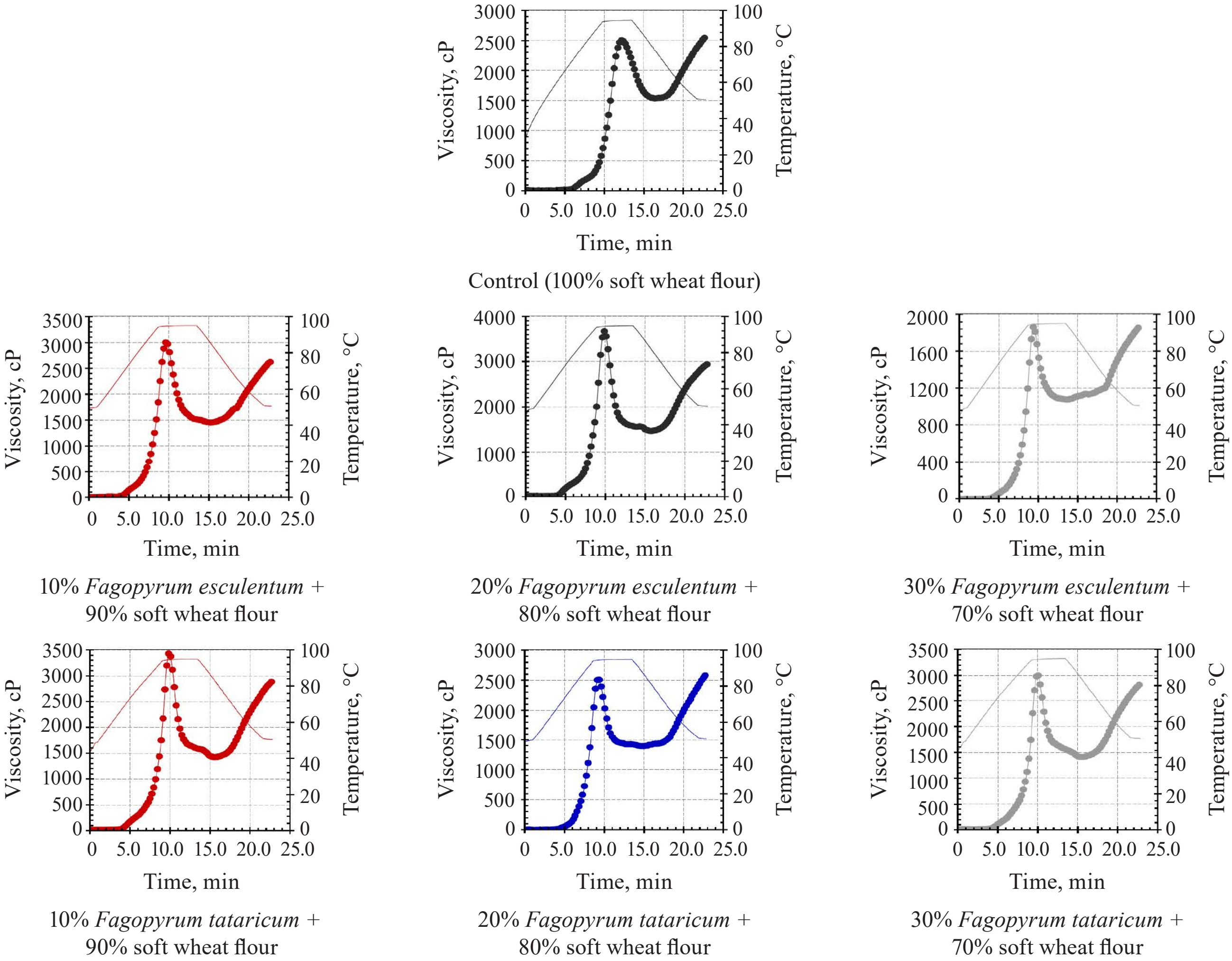


Figure 2 Rapid viscoanalyzer parameters of dough samples with 10, 20, and 30% *Fagopyrum esculentum*/*Fagopyrum tataricum*

the pasting profile of flour samples also revealed that flour blends had lower viscosities and pasting temperature. Gluten-free flour proved able to alter the amylose/amylopectin ratios of starches and the gluten content [28, 29].

Chemical composition of biscuit samples. This research stage featured the effect of adding 10, 20, and 30% *F. esculentum*/*F. tataricum* to soft wheat flour. The biscuits fortified with *F. esculentum*/*F. tataricum* contained more protein, fat, ash, and crude fiber than the control sample fortified with soft wheat flour (Table 5). The biscuits with 72% soft wheat flour had more carbohydrates than total carbohydrates. *F. esculentum* and *F. tataricum* were rich in iron, copper, and magnesium, which could be responsible for the increased ash concentration [30]. The rise in the moisture content may be attributed to the higher protein content. Mustafa *et al.* demonstrated that the moisture content of bread rose as the protein level increased [31]. The fat content of the biscuit samples with *F. esculentum* and *F. tataricum* was higher than that of the biscuits with soft wheat flour because buckwheat flour tends to retain oil during baking [32–34]. Higher oil retention improves the texture and flavor retention of biscuits. The protein content in the biscuits increased together with the concentration of *F. esculentum*/*F. tataricum*, probably, because soft wheat flour was low-protein.

Color parameters. Color is a crucial sensory element that directly affects customer choice for any product, especially bakery items. We analyzed the color properties of the biscuits using a Hunter laboratory colorimeter (Table 6). The Hunter *L* scale spanned from 0 black to 100 white, whereas Hunter *b* scale ranged from negative blue to positive yellow. The biscuits with *F. esculentum*/*F. tataricum* were darker than the control. The lightness (L^*) and redness (b^*) values decreased as the percentage of *F. esculentum*/*F. tataricum* increased. The yellowness (a^*) increased together with the share of *F. esculentum*/*F. tataricum*. Both *F. esculentum* and *F. tataricum* flours were darker (lower L^*) than soft wheat flour. Naturally, the biscuits with *F. esculentum*/*F. tataricum* were darker in color. These results concurred with other publications [35–37]. The Maillard browning and sugar caramelization during baking are believed to cause brown pigments [38]. These browning events depend on several variables, including water activity, pH, temperature, sugars, and the type and proportion of amino compounds [39, 40]. Sugar caramelization

Table 5 Chemical composition of biscuits with *Fagopyrum esculentum*/*Fagopyrum tataricum*, %wd

Samples	Moisture	Protein	Oil	Ash	Fiber	Carbohydrate
Control (100% soft wheat flour)	4.50[e] ± 0.08	10.65[f] ± 0.15	28.37[f] ± 0.22	0.35[e] ± 0.01	0.72[f] ± 0.10	59.91[a] ± 0.65
10% *Fagopyrum esculentum* + 90% soft wheat flour	4.75[d] ± 0.05	10.90[d] ± 0.17	28.50[d] ± 0.15	0.40[d] ± 0.03	1.15[e] ± 0.09	59.05[b] ± 0.52
20% *Fagopyrum esculentum* + 80% soft wheat flour	5.00[bc] ± 0.07	11.15[b] ± 0.10	28.65[b] ± 0.12	0.42[cd] ± 0.05	1.50[d] ± 0.07	58.28[c] ± 0.48
30% *Fagopyrum esculentum* + 70% soft wheat flour	5.15[ab] ± 0.10	11.35[a] ± 0.19	28.70[a] ± 0.17	0.45[bc] ± 0.07	1.85[c] ± 0.11	57.65[d] ± 0.29
10% *Fagopyrum tataricum* + 90% soft wheat flour	4.80[cd] ± 0.12	10.80[e] ± 0.22	28.40[e] ± 0.14	0.42[cd] ± 0.09	1.50[d] ± 0.08	58.88[e] ± 0.42
20% *Fagopyrum tataricum* + 80% soft wheat flour	5.05[ab] ± 0.9	11.00[c] ± 0.13	28.50[d] ± 0.10	0.48[b] ± 0.06	2.00[b] ± 0.15	58.02[f] ± 0.35
30% *Fagopyrum tataricum* + 70% soft wheat flour	5.25[a] ± 0.11	11.15[b] ± 0.16	28.60[c] ± 0.19	0.55[a] ± 0.04	2.45[a] ± 0.19	57.25[g] ± 0.22
LSD at 0.05	0.235	0.033	0.021	0.035	0.136	0.0414

The results are presented as means for triplicate analyses ± standard deviation (SD)

The data marked with superior letters are significantly different ($p \leq 0.05$)

Table 6 Color attributes of biscuits with *Fagopyrum esculentum*/*Fagopyrum tataricum*

Samples	L^*	a^*	b^*	a/b	Saturation	ΔE^*
Control (100% soft wheat flour)	65.10[a] ± 0.45	6.80[f] ± 0.16	32.50[a] ± 0.35	0.21[g] ± 0.01	33.20[a] ± 0.22	73.08[a] ± 1.15
10% *Fagopyrum esculentum* + 90% soft wheat flour	60.80[b] ± 0.54	10.80[d] ± 0.19	27.71[c] ± 0.40	0.39[e] ± 0.30	29.74[bc] ± 0.35	67.68[b] ± 1.22
20% *Fagopyrum esculentum* + 80% soft wheat flour	55.41[c] ± 0.49	12.50[b] ± 0.25	25.15[d] ± 0.39	0.50[c] ± 0.01	28.09[e] ± 0.17	62.12[d] ± 1.33
30% *Fagopyrum esculentum* + 70% soft wheat flour	49.68[d] ± 0.64	13.26[a] ± 0.13	22.56[e] ± 0.50	0.59[b] ± 0.04	26.19[cd] ± 0.19	56.15[e] ± 1.38
10% *Fagopyrum tataricum* + 90% soft wheat flour	58.20[bc] ± 0.75	10.10[e] ± 0.11	29.00[b] ± 0.29	0.35[f] ± 0.00	30.71[b] ± 0.27	65.80[c] ± 1.19
20% *Fagopyrum tataricum* + 80% soft wheat flour	49.33[d] ± 0.62	11.00[c] ± 0.25	25.50[d] ± 0.32	0.43[d] ± 0.02	27.77[de] ± 0.15	56.61[e] ± 1.29
30% *Fagopyrum tataricum* + 70% soft wheat flour	38.40[e] ± 0.55	13.20[a] ± 0.16	21.19[f] ± 0.25	0.62[a] ± 0.03	24.96[f] ± 0.26	45.80[f] ± 1.11
LSD at 0.05	0.128	0.105	0.346	0.0175	1.751	1.365

The results are presented as means for triplicate analyses ± standard deviation (SD)

The data marked with superior letters are significantly different ($p \leq 0.05$)

and the Maillard processes also cause browning in high-sugar biscuit formulations [41].

Baking quality. Table 7 describes the following baking parameters of biscuits: weight (g), volume (cm^3), specific volume (v/w), diameter (cm), thickness (cm), and spread ratio (%). The diameter of the *F. esculentum*/*F. tataricum* biscuits decreased slightly with increasing the substitution percentage compared to control biscuits. The samples with 10% *F. esculentum* had the biggest diameter (6.63 cm), while the samples with 20% *F. esculentum* had a small diameter (6.52 cm). However, the height of *F. esculentum*/*F. tataricum* biscuits decreased relative to the control sample, except for the sample with 10% *F. esculentum*. The spread ratio normally corresponds to the diameter-to-height ratio, which serves as a quality indicator. Therefore, premium biscuits should have a high spread ratio [42]. *F. esculentum*/*F. tataricum* proved to enhance the spread ratio, although the sample with 20% *F. tataricum* had the lowest spread ratio value of 6.06 cm. The rise in spread ratio may be due to the dilution of gluten caused by the increased proportion of *F. esculentum*/*F. tataricum* in the formulation. The samples with *F. esculentum*/*F. tataricum* had a greater protein and dietary fiber content, which reduced the spread ratio because these ingredients have a greater water-binding capacity. As a result, they reduced the amount of water available to dissolve sugars and prevented the biscuits from spreading [43, 44]. As the gluten protein diluted and the fiber and gluten interacted, the extra fiber added to wheat flour together with *F. esculentum*/*F. tataricum* had a decisive impact on the development of gluten networks [43, 45]. *F. esculentum*/*F. tataricum* decreased the weight and volume of biscuits as the replacement levels rose. The formulation of biscuits

Table 7 Baking quality of biscuits with *Fagopyrum esculentum*/*Fagopyrum tataricum*

Samples	Weight, g	Volume, cm^3	Specific volume, cm^3/g	Diameters	Height	Spread ratio
Control (100% soft wheat flour)	26.25^a ± 1.02	36.75^b ± 0.11	1.40^a ± 0.03	6.60^a ± 0.17	1.08^a ± 0.01	6.15^a ± 0.16
10% *Fagopyrum esculentum* + 90% soft wheat flour	23.35^b ± 0.68	38.05^a ± 0.19	1.63^a ± 0.06	6.63^a ± 0.11	1.10^a ± 0.00	6.07^a ± 0.11
20% *Fagopyrum esculentum* + 80% soft wheat flour	21.55^c ± 1.15	32.50^g ± 0.22	1.51^a ± 0.05	6.52^a ± 0.15	0.98^a ± 0.01	6.69^a ± 0.19
30% *Fagopyrum esculentum* + 70% soft wheat flour	21.75^c ± 0.60	33.09^e ± 0.17	1.52^a ± 0.10	6.53^a ± 0.22	0.99^a ± 0.03	6.59^a ± 0.15
10% *Fagopyrum tataricum* + 90% soft wheat flour	18.30^d ± 0.36	32.68^f ± 0.10	1.79^a ± 0.07	6.50^a ± 0.13	0.99^a ± 0.05	6.60^a ± 0.21
20% *Fagopyrum tataricum* + 80% soft wheat flour	21.40^c ± 0.48	36.28^c ± 0.25	1.70^a ± 0.02	6.54^a ± 0.19	1.08^a ± 0.07	6.06^a ± 0.12
30% *Fagopyrum tataricum* + 70% soft wheat flour	23.50^b ± 0.52	35.28^d ± 0.13	1.52^a ± 0.04	6.56^a ± 0.23	1.05^a ± 0.10	6.28^a ± 0.17
LSD at 0.05	1.324	0.169	0.506	0.404	0.249	1.204

The results are presented as means for triplicate analyses ± standard deviation (SD)

The data marked with superior letters are significantly different ($p \leq 0.05$)

Table 8 Sensory properties of biscuits with *Fagopyrum esculentum*/*Fagopyrum tataricum*: mean values

Samples	Color (20)	Taste (20)	Odor (20)	Crispiness (20)	Appearance (20)	Overall acceptability (100)
Control (100% soft wheat flour)	18.22^a ± 0.32	19.04^a ± 1.16	18.52^a ± 0.36	17.44^b ± 0.50	19.02^a ± 0.32	92.24^a ± 3.15
10% *Fagopyrum esculentum* + 90% soft wheat flour	17.12^c ± 0.44	18.64^a ± 1.22	18.16^a ± 0.52	18.02^{ab} ± 0.82	19.00^a ± 0.28	90.94^{ab} ± 2.65
20% *Fagopyrum esculentum* + 80% soft wheat flour	17.22^c ± 0.38	18.74^a ± 0.68	17.85^a ± 0.69	18.34^a ± 0.79	18.82^a ± 0.86	91.00^{ab} ± 3.54
30% *Fagopyrum esculentum* + 70% soft wheat flour	15.86^d ± 0.52	16.64^b ± 0.92	16.66^b ± 0.56	18.20^a ± 1.03	16.62^b ± 0.64	83.98^d ± 3.22
10% *Fagopyrum tataricum* + 90% soft wheat flour	18.28^a ± 0.61	18.50^a ± 0.86	18.22^a ± 0.62	18.30^a ± 0.85	16.56^b ± 0.38	88.92^c ± 2.70
20% *Fagopyrum tataricum* + 80% soft wheat flour	17.76^b ± 0.55	18.86^a ± 0.90	18.30^a ± 0.78	16.66^c ± 0.52	16.96^b ± 0.91	89.06^{bc} ± 3.05
30% *Fagopyrum tataricum* + 70% soft wheat flour	17.34^{bc} ± 0.45	18.62^a ± 1.09	18.58^a ± 0.84	18.52^a ± 0.92	16.42^b ± 0.76	89.90^{bc} ± 3.08
LSD at 0.05	0.456	0.697	0.772	0.728	0.833	1.945

The results are presented as means for triplicate analyses ± standard deviation (SD)

The data marked with superior letters are significantly different ($p \leq 0.05$)

often depends on the quality of the components employed [46]. Thus, the specific volume has a significant effect on the quality of the finished product.

Sensory properties. Sensory properties affect the purchase decision. Sensory evaluation of biscuits usually includes such parameters as color, taste, smell, crispiness, and overall acceptability. Table 8 and Fig. 3 demonstrate the sensory properties of the experimental biscuits. The increasing level of *F. esculentum*/*F. tataricum* in the biscuit formulation affected the color of all biscuit samples compared to the control, but there was no significant difference between the color of the biscuit control sample and biscuit with 10% *F. tataricum* (Table 8). Also, the increasing level of *F. esculentum*/*F. tataricum* did not affected significantly on the taste and odor of the biscuit compared to the control sample except 30% *F. esculentum*. As for crispiness, all tested samples had slight differences. There was no significant difference in the appearance of 10 and 20% *F. esculentum* compared to the control sample. Also, there was no significant differences between the 30% *F. esculentum* buiscit and all the samples with *F. tataricum*, while all they significantly decreased compared to the control sample. The same trend between appearance and overall acceptability was noticed. Also, these results were confirmed by the results of the physical properties of biscuits.

Texture profile analysis. Table 9 and Fig. 4 illustrates the texture values for the biscuit samples. Hardness is known to depend on the compressive strength of biscuits. The instrumental hardness test revealed that hardness increased together with the quantity of *F. esculentum*/*F. tataricum*. The immediate increase in hardness

Control (100% soft wheat flour)

10% *Fagopyrum esculentum* +
90% soft wheat flour

20% *Fagopyrum esculentum* +
80% soft wheat flour

30% *Fagopyrum esculentum* +
70% soft wheat flour

10% *Fagopyrum tataricum* +
90% soft wheat flour

20% *Fagopyrum tataricum* +
80% soft wheat flour

30% *Fagopyrum tataricum* +
70% soft wheat flour

Figure 3 Photos of biscuits with *Fagopyrum esculentum*/*Fagopyrum tataricum*

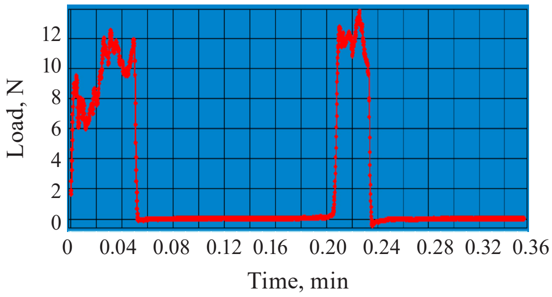
Table 9 Texture profile analysis of biscuits with *Fagopyrum esculentum*/*Fagopyrum tataricum*

Samples	Hardness, N	Adhesiveness, M·J	Resilience	Springiness, mm	Fracturability
Control (100% soft wheat flour)	12.26	4.00	0.04	1.51	8.98
10% *Fagopyrum esculentum* + 90% soft wheat flour	13.55	2.00	0.03	2.07	5.70
20% *Fagopyrum esculentum* + 80% soft wheat flour	10.93	4.00	0.03	2.63	2.01
30% *Fagopyrum esculentum* + 70% soft wheat flour	12.38	0	0.06	1.39	8.20
10% *Fagopyrum tataricum* + 90% soft wheat flour	16.83	7.00	0.02	4.24	2.29
20% *Fagopyrum tataricum* + 80% soft wheat flour	18.13	2.00	0.01	1.61	7.04
30% *Fagopyrum tataricum* + 70% soft wheat flour	17.49	0	0.04	0.47	1.04

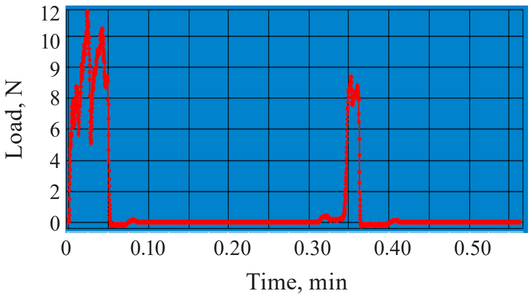
was from 12.26 N for the control biscuits to 17.49 N for the samples with 30% *F. tataricum*. The increase in hardness might have been caused by the increased dietary fiber content with its high water-absorbing capacity. The initial region of negative force produced by the bite quantified the adhesion. In this study, adhesiveness was the negative force area for the first bite. The samples with 20% *F. esculentum* and 10% *F. tataricum* demonstrated the maximal adhesiveness values of 4.0 and 7.0 g/cm, respectively.

Springiness reflects the strength of internal links and the degree to which it may be deformed without breaking *F. esculentum*/*F. tataricum* enhanced the springiness of the experimental samples compared to control except 30% *F. esculentum* and 30% *F. tataricum*. The sample with 10% *F. tataricum* had the highest springiness (4.24%). These experimental results contradicted those reported in [34, 47].

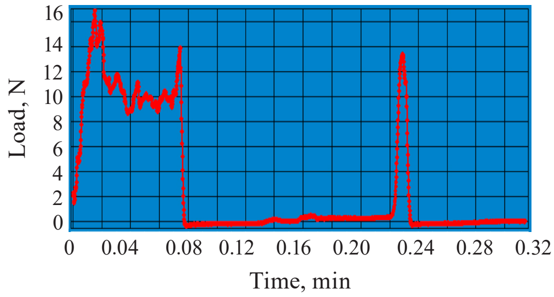
All the experimental biscuit samples exhibited a slight drop in resilience scores, depending on the *F. esculentum*/*F. tataricum* concentrations. Resilience measures the speed and force with which a sample recovers from deformation. In our study, the sample with 30% *F. esculentum* showed the maximal resilience value of 0.06.



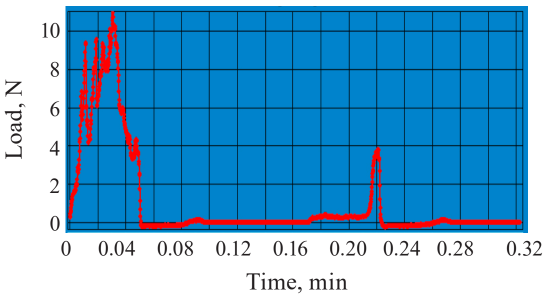
Control (100% soft wheat flour)



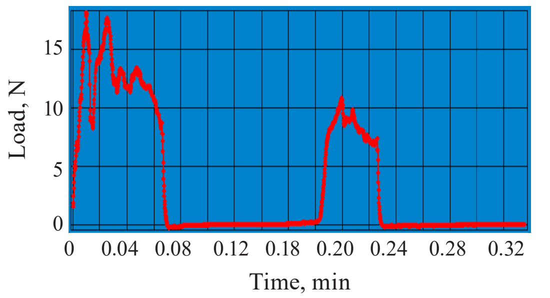
10% *Fagopyrum esculentum* + 90% soft wheat flour



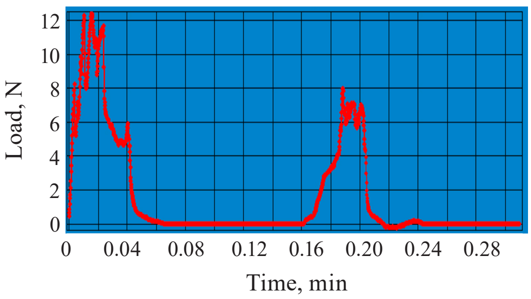
10% *Fagopyrum tataricum* + 90% soft wheat flour



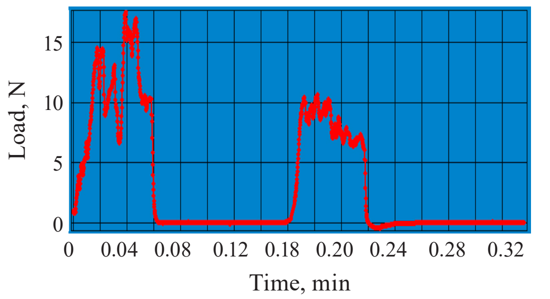
20% *Fagopyrum esculentum* + 80% soft wheat flour



20% *Fagopyrum tataricum* + 80% soft wheat flour



30% *Fagopyrum esculentum* + 70% soft wheat flour



30% *Fagopyrum tataricum* + 70% soft wheat flour

Figure 4 Texture profile of biscuits with *Fagopyrum esculentum*/*Fagopyrum tataricum*

CONCLUSION

Wheat flour biscuits fortified with buckwheat flour had an improved nutritional value. According to the obtained results, the overall acceptability of all the experimental biscuits fell within a suitable range but the biscuits with buckwheat flour up to 20% demonstrated the highest quality. Higher concentrations of *Fagopyrum esculentum* Moench. or *Fagopyrum tataricum* (L.) Gaertn. adversely affected the baking quality, color, and texture of the experimental biscuits. However, the samples with 10% *F. esculentum* or *F. tataricum* demonstrated no significant changes in the sensory profile. Finally, we can recommend to use 10% buckwheat to improve biscuit quality and alleviate shortages of raw wheat materials.

CONTRIBUTION

The authors were equally involved in the research and are equally responsible for any potential cases of plagiarism.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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