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Preparation and Quality Characteristics of Biscuits Fortified with Oat and Flaxseed

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Abstract

The present study aimed to formulate and evaluate biscuits made from different levels of whole oat flour (WOF) (5, 10 and 15%) and roasted flaxseed flour (RFF) (15, 20 and 25%). Biscuits made from wheat flour (WF) and different mixtures were evaluated for physicochemical, texture profile, color parameters and sensory characteristics. WOF and RFF were found to be rich in protein, fat, mineral and fiber content compared to WF. Hence, biscuit samples were significantly ($P \leq 0.05$) higher in protein, fat, ash and fiber contents than the control sample. Color and texture measurements were undertaken with the help of the Hunter Lab and Texture Analyzer, respectively. The results indicated that as the concentration of WOF and RFF in the blend increased, the biscuits became darker in color. The spread factor significantly ($P \leq 0.05$) increased with the increase in WOF in biscuits compared to other biscuit samples. The texture profile analysis (TPA) of biscuits showed that RFF biscuits had the lowest hardness values. Sensory panelists rated biscuits containing 5% WOF flour as highly acceptable in relation to their overall acceptability scores and as being closest to the control biscuits. RFF biscuits were accepted for up to 20%. Beyond this level of replacement, the appearance and flavor of the biscuits were adversely affected.

Keywords: Wheat flour; Whole oat flour; Roasted flaxseed; Biscuits; Baking quality; Sensory properties.

1. Introduction

The biscuit industry has a diverse group of biscuit varieties ranging from high to low in sugar or fat, different flavors and other combinations. In addition, biscuits are the most important bakery product used as snacks by school-going children and adults, as they appeal to all age groups. The major contributing factors to increase demand for biscuit consumption are palatable taste, digestibility, variety in crispiness, better shelf life, reasonable costs, lightweight and ease of transportation [1]. Commercially, most available biscuits are prepared from refined WF, which is deficient in some essential amino acids and has low fiber content, minerals and other nutrients [2]. Hence, the manufacturing ofbiscuits rich in dietary fiber, protein and bioactive agents is of growing interest to both manufacturers and consumers [3]. Recently, cereal-based foods like bread, biscuits, cakes and other bakery products have been enriched with different nutrients by adding oat [4- 7] and flaxseed [2, 8–11] as revised and reported in the previous studies.

Oat *(Avenasativa)* is an underutilized cereal belonging to the *Poaceae* family. It was used as animal feed and to a lesser extent, as human food. Oat is well known for its functional attributes because of its relatively high protein content with many essential amino acids (threonine, methionine, cysteine, isoleucine, tryptophan, valine, histidine, leucine, methionine, phenylalanine and tyrosine), fiber,

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especially beta-glucan, vitamin B, and mineral contents [12, 13, 6]. Many studies have proved that beta-glucan has beneficial effects on diseases such as diabetes mellitus, obesity, hypertension and dyslipidemia, as well as lowering cholesterol and reducing the risk of heart disease [14, 6]. Moreover, it has great importance in celiac disease due to the lack of gluten[4]. Many studieshave recommended using oat flour as a source of dietary fiber in various products such as bread and biscuits[14, 4, 6]. Chauhan et al. [4] stated that oat can serve as an important constituent of functional foods for promoting a healthy lifestyle in society.

Flaxseed (*Linumusitatissimum*) is an important oilseed crop. Recently, the importance of flaxseed in the human diet has increased due to its unique nutrient profile. Flaxseed is rich in bioactive components that provide health benefits, including alpha-linolenic acid, protein, lignans, dietary fiber and soluble mucilage [11]. In addition, it is a good source of calcium, manganese, vitamins and omega-3 [15]. Flaxseed has medicinal benefits and has been used as a source of health-giving additives in many bakery products. Flaxseed consumption in the diet reduces the risk of serious diseases like coronary diseases, diabetes, obesity, gastrointestinal, renal and bone disorders, cardiovascular risk and certain types of cancers, particularly hormone-dependent cancers (such as breast and prostate cancer) [2, 11]. About two-thirds of flaxseed fiber is insoluble, which increases the bulk in the digestive system, thus aiding in digestion and preventing constipation [16]. Studies reported the incorporation of flaxseed in various value-added products such as cookies [17], biscuits [16], pasta, noodles, macaroni, spaghetti and snacks [2]. Some studies showed that a flaxseed substitution level of up to 20 percent led to good product acceptability [11].

Nowadays, there is an increase in the use of functional nutrient sources in the human diet, which, besides their nutritive value, also have positive effects on our health. Incorporation of other flour sources in biscuit formulas can reduce their sensory quality and cause less consumer acceptance. As a result, there are challenges in producing biscuits with higher functional properties, higher quality and consumer acceptability that are equivalent to traditional products. Therefore, the objective of the present study was to improve the nutritional quality of biscuits and evaluate the effect of partial substitution of WF with WOF and RFF on the chemical, physical and sensory characteristics of the biscuits.

2. Materials and methods

2.1. Materials

WF (72% extraction) was obtained from the North Cairo Flour Mills Company, Egypt. Flaxseed, WOF, shortening, sugar, baking powder, salt (sodium chloride), whole milk and vanilla were obtained from one of the Dokki local market, Egypt.

2.2. Methods

2.2.1. Flaxseed preparation

Flaxseed was prepared as presented in figure (1). Flaxseed was cleaned manually to remove dust, damaged seeds, and other impurities such as weeds and metals. Clean flaxseed was roasted until a nutty flavour developed before being ground to a fine powder by a locally milling machine (coffee grinder-w Moulinex, France). The resultant flour was packed and sealed in polyethylene bags until analyzed.

2.2.2. Blends preparation

WF (72% extraction) was well blended with WOF at various levels (5, 10, and 15%) and RFF at various levels (15, 20, and 25%) to produce individual mixtures.

Flaxseed

↓

Cleaning

↓

Roasting (180° C/15 minutes)

↓

Grinding

↓

Sieving (20 or 40 mesh)

↓

Packing in polyethylene bags

Fig. 1. Flow chart for preparation of RFF.

2.2.3. Preparation of biscuits

Biscuit samples were prepared according to the method of AACC [18] with some modifications to the recipe. So, the seven different biscuit recipes were prepared as shown in table (1). Baking was carried out at 180ºC for 20 min. Biscuit samples were cooled and stored in polyethylene bags.

Table 1. Ingredients used in producing different biscuit blends

Ingredients (gram)	Control	WOF			RFF		
		5%	10%	15%	15%	20%	25%
WF	100	95	90	85	85	80	75
WOF	-	5	10	15	-	-	-
RFF	-	-	-	-	15	20	25
Sugar	40	40	40	40	40	40	40
Butter	28	28	28	28	28	28	28
Whole milk	32	32	32	32	32	32	32
Baking powder	1.1	1.1	1.1	1.1	1.1	1.1	1.1
vanilla	1	1	1	1	1	1	1
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5

WF: Wheat flour,WOF: Whole oat flour andRFF: Roasted flaxseed flour.

2.2.4. Proximate chemical composition of raw materials and biscuits

WF, WOF, RFF and biscuit samples have been analyzed for the following constituents: moisture, protein, fat, ash and crude fiber according toAOAC [19]. The percentage of crude protein has been calculated by multiplying the total nitrogen content by the conversion factor (WF and biscuits (N) × 6.25), (WOF (N) × 5.36) and (RFF (N) × 5.7). The analyses have been done in triplicate. Carbohydrates were calculated by the difference as follows:

Carbohydrates (%) = 100 - [moisture% + proteins% + fat% + ash% + crude fiber%].

2.2.5. Calorific value

Total calories of samples were calculated according toJames [20] formula as follows:

Total calories (Kcal/100 g) = (Fat × 9 Kcal) + (Protein × 4 Kcal) + (Total carbohydrate × 4 Kcal).

2.2.6. Mineral composition of raw materials

Macro- and microelements were determined by the dry ashing method, according toJones *et al.* [21].Calcium (Ca) and magnesium (Mg) were determined by the versenate (EDTA) method [22].Phosphorus (P) was determined by the ascorbic acid method [23].Potassium (K) and sodium (Na) were determined by the flame photometric technique [24].Manganese (Mn), iron (Fe), copper (Cu),zinc (Zn), and nickel (Ni) were determined by inductively coupled plasma (ICP) emission spectroscopy [25].

2.2.7. Physical characteristics of biscuits

Diameter (mm), thickness (mm),spread ratio, weight (gram), volume (ml) and specific volume (ml/gram) were determined as described in AACC [18], and the spread factor of biscuits was calculated according to Youssef et al. [12] as the following equations:

Spread ratio = diameter / thickness.

Spread factor = (Spread ratio of the sample / Spread ratio of control sample) × 100.

2.2.8. Color determinations

Color parameters of biscuit samples were determined using Hunter Lab (UltraScan PRO Spectrophotometer, USA). The instrument was calibrated each time with the with the Hunter white tile. The color coordinates L^*, a^* and b^* were measured according to the device formula. Hue and chroma (the color intensity) were calculated according to the following equations [26]. The values of ΔE (total color difference) were calculated as follows [27]**:**

Hue = $\tan^{-1} [b^*/a^*]$

Chroma = 1/2 square root of $[a^{*2} + b^{*2}]$

$\Delta E = (L^{*2} + a^{*2} + b^{*2})^{1/2}$

Where ($a^*=a^*-a^*_0$), ($b^*=b^*-b^*_0$) and ($L^*=L^*-L^*_0$). Subscript "O" indicates the color of the control.

2.2.9. Sensory properties of biscuits

The sensory evaluation of the prepared biscuit samples was carried out, according to Linda et al. [28], by twenty semi-trained panelists from the Food Technology and Nutrition Institute staff at the National Research Centre, Egypt. Sensory evaluation was done in order to determine consumer acceptability. A numerical hedonic scale ranging from 1 to 20 (where 1 is the most disliked and 20 is the most liked) was used for sensory evaluation.

2.2.10. Texture analysis

The texture properties of hardness, adhesiveness, cohesiveness, gumminess and resilience were measured by using a texture analyzer (Brookfield, CT3-10 kg, USA) as described by Pop et al. [29].

*2.2.11. **Statistical analyses***

Standard Deviation (SD) calculations have been done using the software Excel 2010. Statistical analysis was conducted with the CoState program using a one-way analysis of variance (ANOVA). The statistical analysis of the obtained results was done with triplicate replications, except for the sensory evaluation data, which had 10 replicates [30]. Data were represented as means followed by ± (SD).

3. Results and discussion

3.1. Proximate chemical composition of raw materials

The proximate chemical composition of raw materials, i.e., moisture, protein, fat, ash, fiber and carbohydrate, was presented in table (2). It was found that there were significant differences ($P \leq 0.05$) mong WF, WOF and RFF compositions in moisture, protein, fat, ash, fiber and carbohydrate content. The data showed that WOF and RFF have complementary nutritional profiles. Moisture content ranged from 12.24% for WF to 2.81% for RFF. The low moisture content of RFF can be explained by the prior roasting process, which removed most of the sample's water content. RFF had a higher protein content (22.61%) than WOF (11.06%) and WF (9.82%). RFF had the highest fat content (36.04%) compared to WOF and WF. The percentages of ash were (4.01, 1.22 and 0.39%) for RFF, WOF and WF, respectively. WF showed the lowest percentage of ash compared to other raw materials due to lower extraction rates. RFF exhibited the highest fiber content, followed by WOF.

Table 2. Proximate chemical composition of WF, WOF and RFF.

Sample	WF	WOF	RFF	LSD at 5%
Moisture %	12.24^{a} ±0.02	10.26^{b} ±0.03	2.81^{c}±0.02	0.047
Protein %	9.82^{c}±0.02	11.06^{b}±0.03	22.61^{a}±0.02	0.054
Fat %	1.34^{c}±0.02	6.74^{b}±0.02	36.04^{a}±0.03	0.057
Ash %	0.39^{c}±0.01	1.22^{b}±0.02	4.01^{a}±0.07	0.095
Fiber %	0.31^{c}±0.01	3.43^{b}±0.30	8.88^{a}±0.02	0.354
Carbohydrate %	75.88^{a}±0.03	67.25^{b}±0.03	25.65^{c}±0.03	0.059

WF: Wheat flour, WOF: Whole oat flour and RFF: Roasted flaxseed flour. Means ± (SD) followed by different letters within rows significantly different ($P \leq 0.05$).

The results presented in table (2) showed that the approximate chemical composition of WOF and RFF contained more nutrients compared to WF. These results are in agreement with those shown in the previous studies on WOF and RFF [11, 12, 31, 32]. The valuable chemical composition of WOF and RFF along with the high carbohydrate content of wheat flour, especially starch, leads to composite flours with good characteristics for biscuit manufacturing [11]. It is reported that flour with high carbohydrate content and low gluten is highly recommended for biscuit manufacturing [34].

3.2. Mineral content of raw materials

The mineral contents of WF, WOF and RFF were stated in table (3) as mg/100 g sample. P, K, Ca, Mg, and Na were represented as macroelements and Fe, Mn, Zn, Cu and Ni were represented as microelements. WOF and RFF contained higher values in all minerals than that of WF. RFF analysis results exhibited higher values for P, K, Mg, Na, Fe, Mn, Zn and Cu which were (630, 830, 420, 285.39, 5.6, 7.78, 6.85 and 1.86 mg/100 gram) compared to WOF and WF, respectively.

A large body of literature has highlighted that WOF and RFF are valuable sources of minerals. For instance, oat is a good source of Mn, Mg, Ca, Zn and Cu [35, 36]. It is shown that flaxseed content values of K, P, Mg and Ca reached (831, 622, 431 and 236 mg/100 gram), respectively [37]. Also, a previous study mentioned that flaxseed is rich in K, which is the most common mineral with a positive effect on the reduction of platelet aggregation and stroke incidence, as well as Mg, which is the second most abundant element in the human body [38]. It is important to note that mineral content could vary in wheat, oat and flaxseed due to different cultivars and could be influenced by external factors such as soil conditions, fertilizers, water availability, climatic conditions and genetic factors. WOF and RFF could be recommended as source of various minerals. Accordingly, the nutritive value of both of them in terms of macro- and microminerals can play a considerable role in enriching biscuits with minerals.

3.3. Proximate chemical composition of biscuits

Table (4) showed the proximate chemical composition of biscuit samples processed from WOF and RFF biscuits at different levels compared to the control biscuits. The moisture content gradually decreased in all biscuit samples as the substitution level of WFO and RFF increased. It ranged from a maximum of 6.26% for the control samples to a minimum of 3% for the 25% RFF biscuit samples. This decrease might be related to the initial low moisture content of RFF (as a raw material) used in WF mixtures. Moreover, the high amount of fat (36.04%) in RFF also caused hydration of the dough and reduced the biscuits' moisture content. It was previously noticed that as the flaxseed flour concentration increased in cookies, the moisture content decreased during baking [39, 38]. It is reported that the moisture content of biscuits was reduced from 3.53 to 2.83% when WF was replaced with 10 to 30% oat flour, respectively [40].Also, carbohydrate content gradually decreased in all biscuit samples as WOF and RFF levels increased. The lowest carbohydrate value was for 25% RFF biscuits.

Results indicated a slight gradual increase in protein, fat, ash and fiber contents with the increased WOF substitution level compared to WF biscuits. Such findings were also obtained byYang et al. [41]; Youssef et al. [12] and Hussein et al. [33]. In a previous study on biscuits, it was reported that the protein and fat contents in biscuits increased with the increase of oat flour level [42]. Also, the incorporation of oat in the cake increased the fiber, protein, fat, and ash content compared to the control sample [43]. When compared to WF and WOF biscuits, the incorporation of RFF has a significant ($P \leq 0.05$) influence on the major components of biscuits. 25% RFF biscuits contained the highest contents of protein, fat, ash and fiber.The calorific values were higher in all fortified biscuits when compared with the control sample. The highest calorific values were found in 20% and 25% RFF biscuit samples due to their high fat content.

Table 3. Mineral analysis of WF, WOF and RFF (mg/100 g sample).

Minerals	**WF**	**WOF**	**RFF**
Macro-elements			
P	80.20	214.00	630.00
K	187.30	643.43	830.00
Ca	39.30	814.47	250.00
Mg	55.20	217.19	420.00
Na	55.60	121.62	285.39
Microelements			
Fe	1.01	0.23	5.60
Mn	5.18	6.13	7.78
Zn	0.55	5.28	6.85
Cu	0.07	1.24	1.86
Ni	0.07	0.59	0.01

WF: Wheat flour, WOF: Whole oat flour and RFF: Roasted flaxseed flour.

Table 4. Proximate chemical composition of biscuits fortified with WOF and RFF at different levels.

Samples	**Moisture**	**Protein**	**Fat**	**Ash**	**Fiber**	**Carbohydrate**	**Caloric value (Kcal)**
	%						
Control	$6.26^{a}\pm0.04$	$8.20^{g}\pm0.08$	$15.20^{e}\pm0.14$	$1.63^{d}\pm0.02$	$0.71^{g}\pm0.02$	$67.97^{a}\pm0.22$	$441.56^{d}\pm0.46$
WOF 5%	$5.73^{b}\pm0.06$	$8.46^{f}\pm0.05$	$15.33^{e}\pm0.15$	$1.66^{d}\pm0.03$	$0.85^{f}\pm0.02$	$67.95^{a}\pm0.22$	$443.66^{c}\pm0.47$
WOF 10%	$5.57^{c}\pm0.02$	$8.85^{e}\pm0.05$	$15.45^{de}\pm0.06$	$1.69^{d}\pm0.10$	$0.99^{e}\pm0.01$	$67.44^{b}\pm0.07$	$444.25^{c}\pm0.47$
WOF 15%	$5.45^{c}\pm0.03$	$9.10^{d}\pm0.08$	$15.67^{d}\pm0.21$	$1.72^{cd}\pm0.15$	$1.16^{d}\pm0.02$	$66.88^{c}\pm0.32$	$444.99^{c}\pm0.43$
RFF 15%	$4.10^{d}\pm0.17$	$10.80^{c}\pm0.06$	$18.18^{c}\pm0.11$	$1.89^{bc}\pm0.09$	$1.95^{c}\pm0.02$	$63.06^{d}\pm0.14$	$459.15^{b}\pm0.68$
RFF 20%	$3.28^{e}\pm0.04$	$11.27^{b}\pm0.04$	$20.91^{b}\pm0.20$	$2.05^{ab}\pm0.05$	$2.32^{b}\pm0.03$	$60.14^{e}\pm0.16$	$473.94^{a}\pm1.21$
RFF 25%	$3.00^{f}\pm0.09$	$11.66^{a}\pm0.05$	$21.32^{a}\pm0.06$	$2.15^{a}\pm0.13$	$2.76^{a}\pm0.02$	$59.08^{f}\pm0.04$	$474.95^{a}\pm0.92$
LSD at 5%	0.143	0.110	0.260	0.171	0.037	0.337	1.375

WF: Wheat flour, WOF: Whole oat flour and RFF: Roasted flaxseed flour. Means ± (SD) followed by different letters within columns significantly different ($P \leq 0.05$).

3.4. Physical characteristics of biscuits

Physical characteristics of biscuit samples prepared by substituting different levels of WF with WOF and RFF compared to control samples figure (3) were determined and tabulated in table (5). When compared to control biscuits, the diameter of WOF and RFF biscuits increased slightly with increasing substitution percentage. Control samples recorded the lowest value in the diameter of 63 mm whereas 15% WOF biscuits presented the highest diameter of 66 mm. Results indicated an increase in WOF or RFF biscuits thickness compared to the control sample, except for 5% WOF biscuits. These results coincide with those of El-Qatey et al. [44].

The biscuit spread ratio represents a ratio of diameter to thickness. It is an indicator of biscuit quality; thus, high-quality biscuits should have a high spread ratio [45]. From the results, it could be seen that the addition of WOF increased the spread ratio, while the addition of RFF reduced the spread ratio. 25% RFF biscuits recorded the lowest spread ratio value of 7.55 compared to other biscuit samples. The increase in spread ratio may be attributed to the dilution of gluten caused by increasing the replacement level of WF with WOF in biscuit manufacture. These results were comparable with the findings of the following studies [46, 44, 2, 33]. The increase in RFF biscuits' content of protein and dietary fiber reduces the spread ratio. The increase in RFF biscuits' content of protein and dietary fiber reduces the spread ratio, as they are known for having more water binding capacity, thus reducing the amount of water that is available to dissolve sugars in the formula and making the biscuits spread less during baking [48, 47].

The spread factor is used to determine the quality of flour used in biscuit production [38]. Spread factor values gradually decreased in RFF biscuits, while values increased in WOF biscuits. These results are in accordance with the findings of other authors [49, 44, 11]. In general, the addition of fiber to WF has a negative effect on the formation of the gluten network due to the dilution of gluten protein and the fiber-gluten interaction [48, 50]. The presence of RFF in the biscuits caused a gradual reduction in weight as the substitution level was increased. 15% WOF biscuits presented a maximum weight of 12.42 gram. This might be due to the different flour quality and fiber. Incorporating WOF and RFF in biscuit blends increased their specific volume. Specific volume has great importance in determining the quality because it is generally influenced by the quality of the ingredients used in the formulation of biscuits [51].

Table 5. Baking quality of biscuits supplemented with different levels of WOF and RFF.

Samples	Diameter (mm)	Thickness (mm)	Spread ratio	Spread factor (%)	Weight (gram)	Volume (ml)	Specific volume (ml/g)
Control	63.00^{d}±0.10	8.06^{d}±0.11	7.81^{bc}±0.12	100.00^{cd}±0.00	11.97^{c}±0.01	32.00^{b}±0.00	2.67^{b}±0.01
WOF 5%	63.86^{c}±0.11	8.10^{d}±0.00	7.88^{bc}±0.01	100.95^{bc}±0.18	12.19^{b}±0.02	32.66^{ab}±0.57	2.68^{b} ±0.04
WOF 10%	65.00^{b}±0.00	8.20^{c}±0.00	7.92^{ab}±1.09	101.49^{ab}±0.00	12.28^{b}±0.07	33.00^{ab}±0.00	2.68^{b}±0.01
WOF 15%	66.00^{a}±1.00	8.23^{bc}±0.05	8.01^{a}±0.17	102.64^{a}±2.20	12.42^{a}±0.16	33.66^{a}±0.58	2.70^{ab}±0.05
RFF 15%	63.16^{d}±0.05	8.20^{c}±0.00	7.70^{cd}±0.01	98.63^{de}±0.09	11.93^{cd}±0.01	32.00^{b}±0.00	2.68^{b}±0.01
RFF 20%	63.43^{cd}±0.05	8.30^{b}±0.00	7.64^{de}±0.01	97.85^{ef}±0.08	11.83^{de}±0.02	32.33^{b}±0.58	2.73^{ab}±0.04
RFF 25%	63.60^{cd}±0.10	8.41^{a}±0.02	7.55^{e}±0.01	96.75^{f}±0.21	11.73^{e}±0.01	32.66^{ab}±1.15	2.78^{a}±0.10
LSD at 5%	0.675	0.087	0.140	1.471	0.118	1.011	0.088

WF: Wheat flour, WOF: Whole oat flour and RFF: Roasted flaxseed flour. Means ± (SD) followed by different letters within columns significantly different (*P* ≤ 0.05).

3.5. Color parameters of biscuits

The color parameters ($L*$), ($a*$), ($b*$), hue angle and chroma for the biscuits were reported in table (6). It was observed that a significant decrease (P ≤ 0.05) in biscuits ($L*$) and the hue angle values with the increase in WOF and RFF levels compared to the control samples, indicating that the biscuits made with these flours had a darker color than the control. Also, an increase in ($a*$) value was observed as the WOF and RFF levels increased. These results are in close agreement with a study by Kaur et al. [52, 53, 38]. It is reported that flaxseed significantly reduced brightness and increased redness in cookies due to the possibility of Maillard reactions related to flaxseed protein and phenolic compounds [39]. El-Qatey et al. [44] stated that biscuits fortified with oat recorded lower (L*) values than the control biscuit samples. This decrease is due to the darkness of the WOF used. Also, the same authors mentioned that (a*) values increased gradually in biscuits with the addition of WOF due to the high percentage of fiber in WOF. There were no differences among WOF biscuits in chroma values. The chroma value decreased with the addition of RFF compared to the control samples.

3.6. Sensory properties of biscuits

Sensory evaluation values of biscuits were presented in table (7) and figure (2). For the color attribute, there were no significant (P ≤ 0.05) differences observed between the control sample and the 5% WOF biscuit. Also, there were no significant (P ≤ 0.05) differences among 10% and 15% WOF biscuits and 15% RFF biscuits. Taste and odor values decreased in 20 and 25% RFF biscuits, whereas there were no differences among 10% and 15% WOF biscuits and control biscuits. 5% WOF biscuits recorded the highest taste score compared to other biscuits. It is reported that the taste and aroma of the samples are positively correlated with the biscuits' content of protein, ash, fat and crude fiber and negatively correlated with moisture and total carbohydrate [11]. The reduction in all RFF biscuits' taste values may be due to their unacceptable taste with increasing substitution levels. Some authors mention a bitter taste in some products with high amounts of flaxseed flour [54].

In both the WOF and RFF biscuit samples, the hedonic appearance values decreased clearly. It was observed that 15% WOF biscuits had a less soft surface than other samples. This can be explained by the fact that panelists visually judged biscuit samples based on their color and the degree of irregularities that could be seen on the surface compared to the control sample. That may be due to the decrease in the biscuits' moisture and carbohydrate contents, as can be seen in table (4) which caused the depreciation of the biscuit surface and a darker color during baking. The appearance was negatively correlated with ash, fat and crude fiber [11]. The decrease in appearance perception with the increase in flaxseed content was also recorded previously in studies performed on biscuits [49, 55, 56] as well as on other bakery products, like cookies [57, 58], muffins [59, 60] and bread [27].

Generally, texture plays a key role in consumers' acceptance of biscuits [11]. 15% RFF biscuits recorded the highest score for texture. In contrast, 15% WOF biscuits were evaluated with the lowest scores in texture evaluation. For overall acceptability (figure 2), 5% WOF biscuits and the control samples were rated with the highest scores, followed by 10% WOF biscuits and 15% RFF biscuits. The mean quality score of the biscuit decreased with the increase in the level of RFF supplementation [15]. Also, increasing WOF in biscuits improves the taste and odor, but it has a negative impact on the texture and color acceptance [40]. Pradhan and Sethi [17] stated that flaxseed incorporation did not modify the color, flavor and taste.

Table 6. Color parameters of biscuits supplemented with different levels of WOF and RFF.

Samples	**Color parameters**					
	L*	***a****	***b****	**Chroma**	**Hue**	**ΔE**
WOF **biscuits**						
0%	$65.65^{a}\pm0.37$	$10.86^{b}\pm1.74$	$38.87^{a}\pm1.40$	$40.37^{a}\pm1.80$	$74.44^{a}\pm1.90$	-
5%	$64.80^{a}\pm0.30$	$14.28^{a}\pm0.18$	$37.54^{a}\pm0.27$	$40.16^{a}\pm0.19$	$69.16^{b}\pm0.38$	$3.77^{c}\pm0.32$
10%	$61.17^{b}\pm0.10$	$14.47^{a}\pm0.13$	$37.33^{a}\pm2.27$	$40.04^{a}\pm2.17$	$68.78^{b}\pm0.99$	$6.23^{b}\pm0.30$
15%	$57.94^{c}\pm1.02$	$15.09^{a}\pm0.10$	$37.28^{a}\pm0.56$	$40.21^{a}\pm0.55$	$67.95^{b}\pm0.22$	$8.96^{a}\pm0.82$
LSD at 5%	1.060	1.655	2.580	2.708	2.056	1.076
RFF biscuits						
0%	$65.65^{a}\pm0.37$	$10.86^{b}\pm1.74$	$38.87^{a}\pm1.40$	$40.37^{a}\pm1.80$	$74.44^{a}\pm1.90$	-
15%	$51.70^{b}\pm0.49$	$12.92^{ab}\pm0.85$	$32.69^{b}\pm0.80$	$35.16^{b}\pm0.78$	$68.43^{b}\pm1.42$	$15.41^{c}\pm0.79$
20%	$48.00^{c}\pm0.81$	$13.40^{a}\pm1.30$	$30.70^{c}\pm0.38$	$33.51^{b}\pm0.82$	$66.45^{bc}\pm1.86$	$19.64^{b}\pm0.82$
25%	$46.03^{d}\pm0.88$	$14.25^{a}\pm0.46$	$30.07^{c}\pm0.30$	$33.28^{b}\pm0.14$	$64.63^{c}\pm0.91$	$21.77^{a}\pm0.95$
LSD at 5%	1.263	2.236	1.585	2.006	2.962	1.708

WF: Wheat flour, WOF: Whole oat flour and RFF: Roasted flaxseed flour. Means ± (SD) followed by different letters within columns significantly different ($P \leq 0.05$).

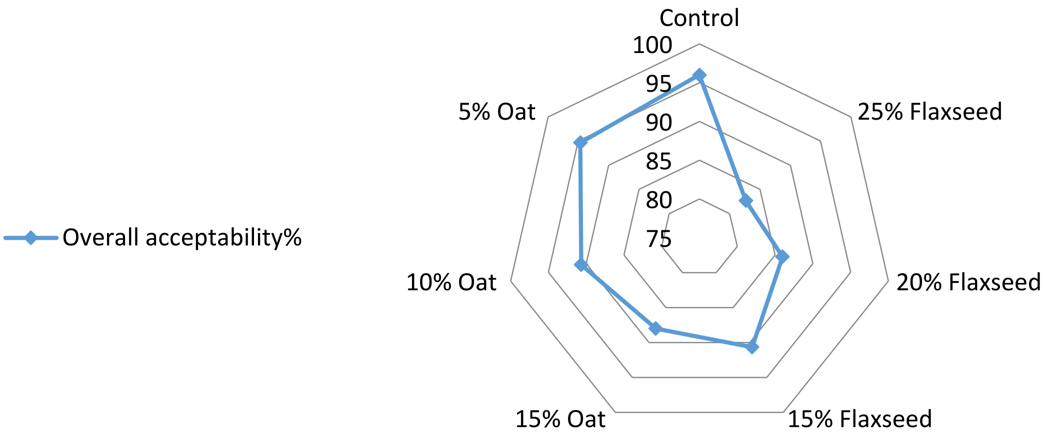

Fig.2. Overall acceptability% of biscuits supplemented with different levels of WOF and RFF.

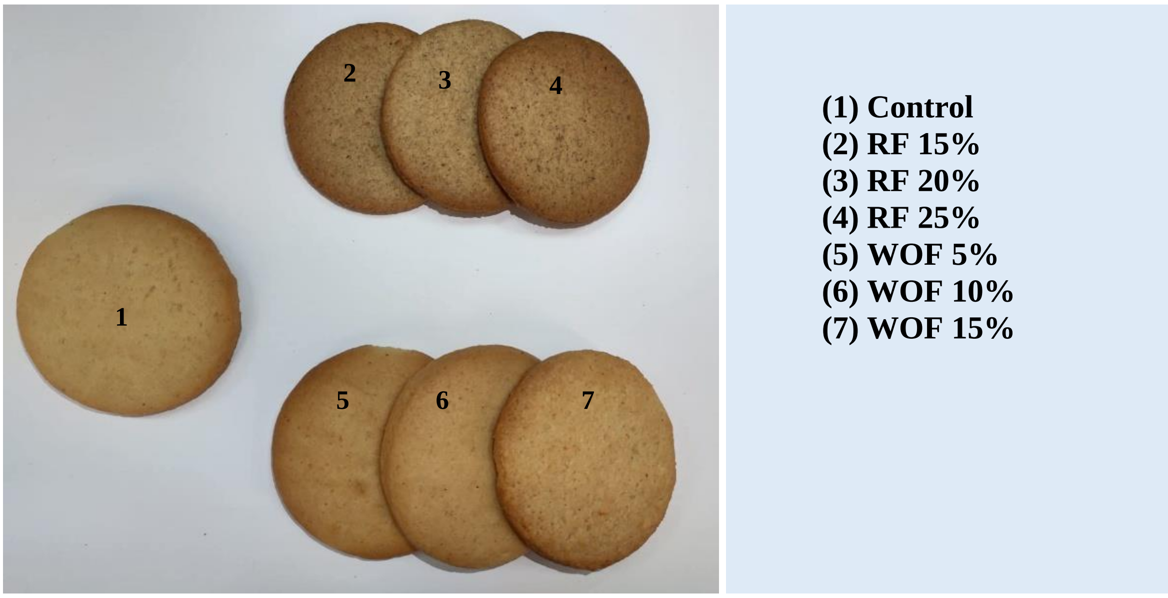

Fig.3. Biscuits supplemented with different levels of WOF and RFF.

Table 7. Sensory characteristics of biscuits supplemented with different levels of WOF and RFF.

Biscuits	Color (20)	Taste (20)	Odor (20)	Appearance (20)	Texture (20)	Overall acceptability %
Control	19.33^{a}	19.00^{b}	19.66^{a}	19.33^{a}	18.66^{ab}	96.00^{a}
WOF 5%	19.00^{a}	19.66^{a}	19.00^{ab}	19.00^{a}	18.00^{abc}	94.66^{a}
WOF 10%	17.33^{b}	19.00^{b}	19.00^{ab}	17.66^{bc}	17.66^{bc}	90.66^{b}
WOF 15%	17.33^{b}	19.00^{b}	19.00^{ab}	15.66^{e}	17.00^{c}	88.00^{c}
RFF 15%	17.00^{b}	18.33^{c}	18.33^{bc}	18.00^{b}	19.00^{a}	90.66^{b}
RFF 20%	16.00^{c}	16.66^{d}	17.66^{cd}	17.00^{cd}	18.66^{ab}	86.00^{d}
RFF 25%	15.00^{d}	15.00^{e}	17.33^{d}	16.66^{d}	18.66^{ab}	82.66^{e}
LSD at 5%	0.661	0.661	0.764	0.764	1.011	1.792

WF: Wheat flour, WOF: Whole oat flour and RFF: Roasted flaxseed flour. Means followed by different letters within columns significantly different ($P \leq 0.05$).

3.7. Texture profile analysis (TPA) of biscuits

Table (8) displays the results of TPA attributes. Hardness is related to the strength of a biscuit's structure under compression. Instrumental analysis of biscuit hardness showed that the hardness value significantly ($P \leq 0.05$) decreased as the amount of RFF increased. Particularly, the values of hardness decreased from 32.54 N for control biscuits to 21.77 N for 25% RFF biscuits. This might be due to its higher content of dietary fiber and protein, which are high water-absorbing capacity components. In addition, due to the high level of fat content (36.04%) found in RFF, these factors led to sticky dough with less extensibility. Previous studies claim that the higher fat content of biscuits may affect the hardness due to its effect on the gluten network (getting interrupted), forming softer biscuits [61, 47, 62, 49, 44].

Adhesiveness is defined as the negative force area for the first bite [63]. The maximum adhesiveness values of 2.66 and 2.33 g.cm had been obtained for 5% WOF and 15% RFF biscuits, respectively. The cohesiveness or consistency indicates the strength of the internal bonds making up the food body and the degree to which it can deform before breaking [64]. The cohesiveness values of the biscuit samples were in the range of 0.080 to 0.026. These results were found to be in accordance with Kaur et al. [2]. Resilience is a measurement of how the sample recovers from deformation both in terms of speed and force [65]. The highest value for biscuits' resilience was 0.06 for 20 and 25% RFF biscuit samples.

Table 8. Texture profile analysis of biscuits supplemented with different levels of WOF and RFF.

Sample	Hardness (N)	Adhesiveness (g.cm)	Cohesiveness	Gumminess (N)	Resilience
Control	32.54^{a}±1.37	1.66^{ab}±0.57	0.080^{a}±0.02	2.42^{a}±0.68	0.05^{abc}±0.02
WOF 5%	32.42^{a}±3.88	2.66^{a}±0.57	0.066^{ab}±0.03	2.17^{ab}±1.23	0.03^{bc}±0.02
WOF 10%	32.36^{a}±1.93	1.33^{b}±0.57	0.053^{abc}±0.01	1.62^{abc}±0.48	0.03^{bc}±0.01
WOF 15%	32.11^{a}±1.60	1.33^{b}±0.57	0.053^{abc}±0.01	1.46^{abc}±0.02	0.04^{abc}±0.02
RFF 15%	27.37^{ab}±6.17	2.33^{ab}±0.57	0.026^{c}±0.01	0.71^{c}±0.20	0.02^{c}±0.01
RFF 20%	23.04^{b}±2.85	2.00^{ab}±1.00	0.050^{bc}±0.01	1.08^{bc}±0.32	0.06^{a}±0.01
RFF 25%	21.77^{b}±8.15	1.33^{b}±0.57	0.053^{abc}±0.01	1.28^{abc}±0.89	0.06^{ab}±0.01
LSD at 5%	7.676	1.146	0.029	1.177	0.032

WF: Wheat flour, WOF: Whole oat flour and RFF: Roasted flaxseed flour. Means ± (SD) followed by different letters within columns significantly different ($P \leq 0.05$).

4. **Conclusion**

The results revealed that WOF and RFF exhibited significantly higher fat, protein, ash and fiber contents than WF. The increased level of WOF and RFF in the blends led to a darker appearance in the biscuit samples. The incorporation of high levels of RFF did not improve the taste or appearance of the biscuits. The addition of WOF increased the spread factor and slightly decreased the hardness of biscuits, whereas RFF decreased both the spread factor and the hardness of biscuits. Therefore, WOF and RFF can be successfully incorporated up to levels of 15% and 20% with WF, respectively. Based on our findings, it could be concluded that the incorporation of WOF or RFF with WF leads to the production of functional and nutritious biscuits with reasonable acceptance.

5. **References**

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