Development and quality evaluation of wheat based cookies enriched with fenugreek and oat flours

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Abstract Cookies are one of the best-known quick snack products. However, the main ingredients used in many countries are wheat and a few cereal seeds. This study was conducted to evaluate the nutritional (chemical composition, physical properties, mineral, and phytochemical) and sensory attributes of cookies produced from wheat alone, and three blends of wheat, fenugreek and oat generated after running a D-optimal design mixture experiment (85:5:10%, 70:10:20%, and 55:15:30%), and when baked at three different temperatures (150, 175, and 200 °C). The results indicated that the cookies made from wheat flour supplemented with fenugreek and oat flours had significantly higher protein, fat, crude fiber and energy contents, but lower carbohydrate content. The anti-nutrient contents (phytic acid and condensed tannin) of fenugreek and oat supplemented cookies increased moderately. The mineral content (Ca, Mg, Fe and Zn) of cookies enriched with fenugreek and oat was also improved. The effect of baking temperature on the different response variables varied, and all in all, 175 °C was an acceptable compromise. The study showed that cookies made from 70% wheat, 10% fenugreek, and 20% oat and baked at 175 °C have the best nutritional content and acceptable sensory attributes.

Keywords Phytochemicals · Baking temperature · Composite flour · Chemical composition · Sensory evaluation

Introduction

Food legumes play a very important role in fulfilling the nutrition requirements of people in many developing countries. Not only that legumes are the main sources of macro- and micronutrients, they also improve the nutritional and environmental sustainability of food systems worldwide (Chaudhary et al. 2018). Fenugreek seed, an annual legume mainly used as a spice crop, has enjoyably bitter taste and is a good source of many nutrients (Krishnaswamy 2008). Fenugreek is a good source of protein, is rich in Mg, Ca, Fe, Zn, Mn, Co, Ba, Cu and Br, and can be used as a source of natural antioxidants in food systems (Pajak et al. 2019).

Among the common cereal grains, oats have high lipid and protein content. The linoleic and oleic acids account for 45.0% and 30.4% of the total lipid in unprocessed oats (Molteberg et al. 1995). Oats have high β -glucan that has anti atherogenic properties (Delaney et al. 2003) that enhance immune response to infection (Ramakers et al. 2006), decrease peak insulin and glucose concentrations (Behall et al. 2006), and decrease serum and plasma cholesterol levels (Naumann et al. 2006).

Cookie, a baked flour confectionery dried down to low moisture content (Bender 2006), is a commonly consumed food throughout the world, which gives more nutrients than any other single food source (Bahatia et al. 1980). Although fenugreek seed and oat flour have lots of nutritional benefits and can be used to enrich the nutritional content of wheat food products, information on such

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products is limited. Fenugreek has been commonly added to wheat bread and fermented breads such as Injera, which is the traditional staple food of Ethiopia, to improve their shelf-life and softness. But, since there is only limited research on the use of fenugreek and oats to enrich cookies, the study was designed to evaluate the chemical and phytochemical composition, the physical quality, and the sensory attributes of cookies formulated using wheat, fenugreek seed and oat flour ingredients with the proportions generated after running a D-optimal design mixture experiment.

Materials and methods

Materials

Fenugreek seed was obtained from Debre Zeit Agricultural Research Center, Ethiopia. King Berd variety wheat grain was obtained from Kulumsa Agricultural Research Center, Ethiopia; and oat grain, sugar, salt, shortening, etc. were purchased from a local open market in Addis Ababa, Ethiopia. All seeds and grains were cleaned manually to remove husks, damaged grains, stones, dust, light materials, stalks, undersized seeds and other extraneous materials.

Preparation of flour and germination

Whole wheat flour was obtained by milling the cleaned wheat grain to powder and sieving through a 710 µm mesh sieve to obtain fine homogenized flour. The flour was packed in polyethylene (PE) bags and stored for further processing. Fenugreek seeds were washed and soaked in potable water for 24 h at an average temperature of 20 °C both during day and night with a Seed:Water ratio of 1:5 (w/v). Then the unimpeded water was drained off and discarded, and the soaked seeds were rinsed twice by boiled and then cooled water to avoid post contamination during germination. The soaked seed was germinated in plastic materials for 72 h at an average temperature of 20 °C with frequent watering and then oven dried at 60 °C for 12 h (Shalini and Sudesh 2004), and ground to pass through 710 µm mesh sieve to obtain fine powder. The cleaned oat grains were fed into a hollow shaft of the huller into the center of a rotor to separate hull from oat groat, and then the oat groat was subjected to kilning and grinding to obtain oat flour.

Blend formulation

Four blends of the three ingredients (wheat, fenugreek, and oat) were created. The first one was 100% wheat that is going to be used as a Control blend. Since 100% of

fenugreek and oat cannot be used, we created a D-optimal mixture experiment design (Montgomery 2017) in Minitab 18 software using 55–85% constraint for wheat, 5–15% constraint for fenugreek, and 10–30% constraint for oat. Then, three of the resulting blends, namely B1 = 85% wheat, 5% fenugreek, and 10% oat; B2 = 70% wheat, 10% fenugreek, and 20% oat; and B3 = 55% wheat, 15% fenugreek, and 30% oat were used. Then Blend was used as the first factor with 4 levels for the statistical analysis.

Recipe and baking

The cookies were prepared according to the formula described in (Tyagi et al. 2007). Accordingly, the recipe was: 380 g flour, 201.4 g sugar, 4.18 g baking powder, 3.38 g salt, 100.7 g sunflower oil as shortening, 182.4 ml water, and 10 ml vanilla extract. After kneading and rolling (sheet of 5 mm) the cookie doughs of all four blends were baked for 10 min in 150, 175, and 200 °C temperatures. This makes Temperature the second factor with 3 levels. All 12 combinations of Blend and Temperature were replicated twice.

Chemical composition and functional properties

The chemical composition (contents of moisture, protein, fat, ash, crude fiber, carbohydrate, and energy) of the baked cookies and the flours (wheat, fenugreek, oat and the three blends) were determined as described in AOAC (1990). Functional properties (water/oil absorption capacity, bulk density, dispersibility, foaming capacity) were determined as described in Adeleke and Odedeji (2010), and pH was determined according to the procedure in AOAC (1990).

Mineral analysis

Mineral analysis was conducted only on the cookies baked at 175 °C because of the suitability of this temperature for manufacturing cookies with acceptable sensory qualities. The mineral (calcium, magnesium, iron and zinc) contents of the cookies were determined by dry ashing according to the procedure of AOAC (2000) using flame atomic absorption spectroscope (F-AAS).

Phytochemical composition

The methods used to determine condensed tannin and phytate were the modified vanillin assay of (Burns 1971) and (Vaintraub and Lapteva 1988), respectively.

Physical quality

The physical quality (weight, diameter, thickness, and spread ratio) of the cookies were measured using digital vernier calipers with 0.01 mm precision.

Sensory analysis

Sensory evaluation of the cookies in terms of color, appearance, odor, crispness, taste, and overall acceptability was done on a 9-point hedonic scale by ten trained panelists following the recommendations described in (McWatters et al. 2003). All panelists have given their informed consent to participate in the study. The sensory evaluation was done at the laboratory of the School of Chemical and Bioengineering, Addis Ababa University.

Experimental design and statistical analysis

The main and interaction effects of Blend (4 levels: Control, B1, B2, and B3) and baking Temperature (3 levels: 150, 175 and 200 °C) on chemical composition (moisture, protein, fat, crude fiber, ash, total carbohydrate, and energy value), phytochemical composition (phytate, and condensed tannin), physical quality (weight, diameter, thickness, and spread ratio), and sensory attributes (color, appearance, odor, crispness, taste, and overall acceptability) were determined using ANOVA of a 4×3 factorial design with two replications. Since only one temperature (175 °C) was used for mineral (calcium, magnesium, iron and zinc) contents, the effect of Blend was determined using a one-way ANOVA. All analyses were completed using the Mixed Procedure of SAS (2014), and the validity of normal distribution and constant variance assumptions on the error terms was verified by examining the residuals as described in Montgomery (2017). Independence assumption was assured through randomization of the experiment (Montgomery 2017). For significant ($p < 0.05$) effects, multiple means comparisons were completed using Tukey's Multiple Means Comparison method at the 5% level of significance.

Results and discussion

Chemical composition and functional properties of flours

Table 1 shows the chemical composition and the functional properties of the flours used to bake the cookies. Among the three types of flour, fenugreek seed flour had the highest content of crude protein, fat, fiber, energy value and the lowest amount of ash, moisture and carbohydrate

content; while oat flour had the lowest amount of fat and energy value (Table 1). These results reveal that the addition of fenugreek in the blend, even in a small proportion (5%), increases the contents of protein, fat, and energy value in the composite flour.

The bulk densities of the flour samples were similar; but water absorbing capacity (WAC) was the highest in fenugreek seed flour (455%) followed by B3 (225%), then by B2 (141%), then by B1 and oat flour (both 130%), and the lowest was in wheat flour (102%) (Table 1). The lower WAC in wheat and oat might be due to smaller availability of polar amino acids in them (Kuntz 1971). Among the ingredients, fenugreek seed flour had the highest (167 ml/g) oil absorption capacity (OAC) followed by wheat (147 ml/g) and then by oat (133 ml/g) (Table 1). All flours have high dispersibility ranging from 51.7% (fenugreek) to 74% (wheat) suggesting that they will reconstitute easily to fine consistent dough or pudding during mixing. Foaming capacity ranged from 3.3 (oat) to 39.6 (fenugreek) and all pH values were between 6.2 and 6.4 (Table 1).

The Analysis of Variance (ANOVA) results that show the significance of the main and interaction effects of Blend and Temperature on chemical composition, phytochemical composition, physical quality, and sensory attributes are shown in Table 2. The interaction effect was significant ($p < 0.05$) on protein, fat, crude fiber, ash and energy value (chemical composition); phytate (phytochemical composition); and diameter and spread ratio (physical quality) suggesting that the difference among the blends are not the same in cookies baked at different temperatures. Table 2 also shows that the main effects of Blend and Temperature are significant on moisture and total carbohydrate (chemical composition); weight and thickness (physical quality); and color (sensory attributes). Only the main effect of Blend was significant on condensed tannin (phytochemical composition), and odor, crispness, taste and overall acceptability (sensory attributes); and only the main effect of Temperature was significant on appearance (sensory attribute) (Table 2).

Chemical composition of the cookies

The moisture content of the cookies ranged from 4.5% (Control blend) to 5.16% (B3: 55% wheat, 15% fenugreek, 30% oat blend), and from 4.63% (200 °C) to 4.96 (150 °C temperature) (Table 3). The increase in moisture content as the proportion of fenugreek in the blend increases is primarily due to high water absorbing/holding capacity of fenugreek flour attributable to its high protein and fiber contents. Carbohydrate content decreased from 73.1% (Control) to 65.5% (B3) as the content of fenugreek and oat increases; and increased from 67.8% (150 °C) to 69.7% (200 °C) as the baking temperature increased. The

Table 1 Chemical composition and functional properties of the wheat flour, fenugreek seed flour, oat flour and the three blends (B1 = 85% wheat, 5% fenugreek, and 10% oat; B2 = 70% wheat, 10% fenugreek, and 20% oat; and B3 = 55% wheat, 15% fenugreek, and 30% oat)

Chemical composition	Wheat	Fenugreek	Oat	B1	B2	B3
Moisture (%)	9.9	6.3	9.8	10.0	9.3	9.3
Protein (%)	13.0	36.9	16.7	17.3	18.5	19.3
Fat (%)	2.3	8.8	1.5	2.5	2.8	3.3
Ash (%)	1.4	1.4	2.6	1.4	1.8	2.1
Crude fiber (%)	1.5	9.0	3.3	3.0	3.5	3.6
Carbohydrate (%)	73.5	46.6	69.4	68.8	67.7	66.0
Energy Value (kcal/100 g)	366	413	358	367	369	371
Functional properties						
Bulk Density (g/ml)	0.46	0.52	0.54	0.47	0.50	0.52
Water absorption capacity (g/g)	102	455	130	130	141	225
Oil absorption capacity (ml/g)	147	167	133	117	140	158
Dispersibility (%)	74.0	51.7	71.7	74.0	70.3	71.0
Foaming capacity	4.5	39.6	3.3	5.8	9.4	18.6
pH	6.3	6.3	6.4	6.2	6.3	6.3

carbohydrate contents obtained in this study are comparable to the 61.0–66.5% reported for biscuits from millet/pigeon pea flour blends (Eneche 1999).

The protein content of cookies increased significantly with increasing blend proportion of fenugreek and oat, but decreased slowly with increasing temperature (Fig. 1). The increase is due to the higher protein content of fenugreek and oat. The decrease could be because of either protein denaturation (removal of protein due to high temperature) or Maillard reaction (a reaction by free amino groups of amino acids and sugars). The fat content of the cookies also increased as the blend proportion of fenugreek and oat increased, but the reduction of fat content as temperature increased was the steepest in B3 (Fig. 1). This reduction may be due to the activity of lipase enzyme, which splits off the fat into free fatty acids and glycerol in the presence of catalyst like moisture, light and heat.

The crude fiber content of the cookies from the blends was significantly higher than those of wheat only (Control) cookies, and as the blend proportion of fenugreek and oat increases crude fiber content increased when baked at 150 °C (Fig. 1). However, crude fiber content of the cookies of B1 increased significantly when the temperature increased from 150 to 175 °C, and that of B2 increased significantly when the temperature increased from 175 to 200 °C. The fiber content of B3 stayed constant as the baking temperature increased (Fig. 1). Further studies on how crude fiber in fenugreek and oat enriched cookies increase with temperature at different paces would be helpful to explain this occurrence. The ash content of B1 and B3 were similar when baked at 150 °C and 200 °C, but showed opposite effect when baked at 175 °C, with B1 giving the highest and B3 giving the lowest ash (Fig. 1).

The gross energy content of cookies ranged from 435 to 456 kcal/100 g, and the lowest content was obtained from

the Control cookies while B2 and B3 blends baked at 150 °C or 175 °C gave the highest energy value (Fig. 1). The reason why blends with higher proportion of fenugreek and oat gave higher energy is because of their high content of crude fat and crude protein. The highest decrease in the energy content of cookies as baking temperature increases was observed in B3 (Fig. 1), which could be due to the decrease in the fat content of the cookies.

Mineral analysis

Mineral analysis of the cookies baked at 175 °C temperature revealed that the effect of Blend was significant ($p < 0.05$) only on calcium content, but not significant on magnesium, iron, and zinc contents. As a result, multiple means comparison was done only on calcium content, and the overall means of magnesium, iron, and zinc were reported. These overall means were 5.9, 1.0, and 2.0 mg/100 g, respectively. Comparison of the mean calcium contents of the four blends showed no significant difference between the mean calcium contents of B2 and B3 (57.5 and 61.0 mg/100 g, respectively), but these means were significantly higher than those obtained from Control (42.0 mg/100 g) and B1 (38.7 mg/100 g). This could be due to the high calcium content of fenugreek and oat flour compared to that in wheat. The difference between the mean calcium contents of Control and B1 was not significant.

Phytochemical analysis

The interaction plot of blend and temperature on phytate (Fig. 1) shows that the highest phytate content (105 mg/100 g) was obtained from cookies of B2 blend and baked at 150 °C, but it reduced with increasing temperature, which

Table 2 ANOVA *p*-values that show the significance of the main and interaction effects of blend and temperature (Temp) on the different response variables

Source of variation (SV)	Chemical composition						
	Moisture	Protein	Fat	Fiber	Ash	Carbohydrate	Energy
Blend	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Temp	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Blend × Temp	0.204	0.007	0.001	0.044	0.001	0.137	0.008
SV	Phytochemical		Physical quality				
	Phytate	Tannin	Weight	Diameter	Thickness	Spread ratio	
Blend	0.001	0.003	0.001	0.001	0.001	0.001	
Temp	0.004	0.080	0.001	0.001	0.001	0.011	
Blend × Temp	0.001	0.306	0.400	0.001	0.955	0.002	
SV	Sensory attributes						
	Color	Appearance	Odor	Crispness	Taste	Overall acceptability	
Blend	0.001	0.266	0.001	0.001	0.001	0.001	
Temp	0.001	0.007	0.906	0.430	0.471	0.109	
Blend × Temp	0.862	0.910	0.870	0.998	0.945	0.953	

Significant effects that require multiple means comparison are shown in bold

could partly be due to leaching into the cooking medium, degradation by heat, and formation of insoluble complexes between phytate and other components such as protein and minerals (Siddhraj et al. 2000). While increasing the baking temperature from 175 to 200 °C increased the phytate content of B1, the change in temperature has not affected the phytate content of the Control and B3 cookies (Fig. 1).

As shown in Table 2, condensed tannin content was significantly affected only by Blend, with B3 (22.0 mg/100 g) giving significantly higher tannin than B1 and B2 (both 15.3 mg/100 g). The tannin content of control cookies was below detection limit, which could be due to the very low tannin content of wheat flour. The higher tannin content in B3 compared to that in B1 and B2 could be due to the higher proportion of fenugreek (lower proportion of wheat that has negligible tannin content).

Physical quality of cookies

The weight and thickness of cookies increased with increasing proportion of fenugreek and oat, but decreased

with increasing temperature (Table 4). The increase in weight of the cookies could be due to the increase in the moisture content of fenugreek; and possibly due to the increase in the bulk density of the blends (Zucco et al. 2011).

The average diameter of cookies ranged from 3.3 to 5.7 cm, with the highest, regardless of the temperature, obtained from the Control cookies (Fig. 1). Figure 1 also shows that the diameter of the composite cookies decreased with increasing temperature. The Control cookies have significantly larger spread ratio regardless of the temperature (Fig. 1); and among the blends, spread ratio decreased with increasing proportion of fenugreek and oat in the cookies baked at 150 °C. However, the difference among the blends in terms of spread ratio shrunk as the temperature increased (Fig. 1). The higher protein content of fenugreek and oat flour used in this study might have contributed to the reduction in spread ratio. Previous studies (McWatters 1978; Singh et al. 1993) also reported a decrease in spread ratio of cookies with increasing protein.

Table 3 Mean moisture (%) and carbohydrate (%) obtained from the cookies of the four blends and the three temperatures

Blend	Moisture (%)	Carbohydrate (%)	Temperature	Moisture (%)	Carbohydrate (%)
Control	4.50 c*	73.1 a	150 (°C)	4.96 a	67.8 c
B1	4.61 c	69.8 b	175 (°C)	4.75 b	68.8 b
B2	4.86 b	66.6 c	200 (°C)	4.63 b	69.7 a
B3	5.16 a	65.5 d			

*Within each column, means sharing the same letter are not significantly different

Fig. 1 Interaction plot of blend and temperature on phytate, protein, fat, crude fiber, ash, energy value, diameter, and spread ratio. Within each plot, means sharing the same letter are not significantly different

Table 4 Mean weight (g) and thickness (cm) obtained from the four blends and the three temperatures

Blend	Weight (g)	Thickness (cm)	Temperature	Weight (g)	Thickness (cm)
Control	8.70 c*	0.523 c	150 (°C)	9.54 a	0.643 a
B1	9.13 bc	0.607 b	175 (°C)	9.29 a	0.608 b
B2	9.36 ab	0.649 a	200 (°C)	8.87 b	0.582 c
B3	9.74 a	0.666 a			

*Within each column, means sharing the same letter are not significantly different

Table 5 Mean color, odor, crispness, taste, and overall acceptability score (out of 9) obtained from the four blends; and mean color, and appearance obtained from the three temperatures

Blend	Color	Odor	Crispness	Taste	Overall acceptability	Temp	Color	Appearance
Control	7.60 a*	7.17 a	6.93 a	7.83 a	7.43 a	150 (°C)	7.13 a	6.73 a
B1	6.77 b	5.87 b	6.53 a	5.50 b	6.53 b	175 (°C)	7.38 a	6.88 a
B2	6.53 b	5.00 c	6.60 a	3.70 c	5.87 c	200 (°C)	5.88 b	6.18 b
B3	6.27 b	3.70 d	5.47 b	3.40 c	4.90 d			

*Within each column, means sharing the same letter are not significantly different

Sensory attributes

Color was the only sensory attribute that was significantly affected by the main effects of both blend proportion and baking temperature, but not by their interaction (Table 2). The mean values of the color scores of the composite (B1, B2, and B3) cookies were not significantly different from each other, and ranged from 6.27 to 6.77 (slightly liked to liked), and the Control cookies had significantly higher score (7.6), which is approximately 8.0 (liked very much) (Table 5). There was no significant difference in the mean color score of cookies baked at 150 °C and 175 °C, but decreased significantly when baked at 200 °C (Table 5), which could be because of the greater amount of the Maillard reaction between reducing sugars and proteins (Raidi and Klein 1983). Appearance was affected only by temperature, with 200 °C giving significantly lower score (Table 5).

Odor of the cookies was significantly affected by blend proportion, and the score declined with increasing proportion of fenugreek and oat (Table 5), with B3 giving the lowest score (3.7, dislike moderately). The crispiness score of cookies from B3 was significantly lower than that of the Control as well as B1 and B2 blends (Table 5). This decrease in crispness of the cookies in B3 might be due to the effect (increase in) of the total fat content of fenugreek seed and oat flour.

The results shown in Table 5 indicate that taste score of the cookies decrease with increasing proportion of fenugreek and oat, which could be because of the bitter taste of fenugreek. The 3.7 and 3.4 taste scores obtained from B2 and B3 suggest that consumers may not like the taste of these blends, and perhaps increasing the amount of sugar in the recipe a bit may address this concern. The overall acceptability of the cookies also declined with increasing proportion of fenugreek and oat, with Control being the most acceptable and B3 the least acceptable cookie (Table 5). The overall acceptability score of B1 (cookies supplemented with 5% fenugreek and 10% oat) was 6.53, which is around slightly liked on the hedonic scale.

Conclusion

The results of the study clearly showed that the use of germinated fenugreek seed and oat flour with wheat, improves the nutritional content of cookies. Therefore, the germinated fenugreek and oat flour could be blended with wheat flour to produce cookies with enhanced physico-chemical properties and acceptable sensory attributes. The study also revealed that higher proportion of fenugreek and oat flour in the composite increases the protein, fiber, ash, energy and mineral contents of the cookies. Specifically, incorporation of around 10% fenugreek flour and 20% oat flour resulted in cookies that have high nutritional content and antioxidant capacity (phytate), and moderate amount of tannin. Although the sensory attributes decreased with increasing proportion of fenugreek and oat, this proportion (B2) baked at 175 °C gives a nutritionally rich and acceptable sensory attributes. Modifying the recipe by increasing the amount of sugar a bit, and increasing the nutritional awareness of consumers by highlighting the benefits of fenugreek and oat supplementation is recommended.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest and that this article does not contain any studies with human or animal subjects.

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