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Chemical composition, rheological properties and cookies making ability of composite flours from maize, sorghum and wheat

B. Amir[1], G. Mueen-ud-din[1], M. Abrar[2], S. Mahmood[1], M. Nadeem[1], A. Mehmood[1]

[1]*Institute of Food Science and Nutrition University of Sargodha Pakistan*
[2]*Ayub agriculture research institute Faisalabad Pakistan*

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Abstract

This study was performed to investigate the chemical and rheological properties of composite flours prepared by using whole wheat flour (*Triticum aestivum*), whole maize flour (*Zea mays*) and whole sorghum flour (*Sorghum bicolor*). Seven blends were prepared by homogenously mixing maize and sorghum flours with wheat flour in the percentage proportions: 0:100, 10:90, 20:80, 30:70, 15:15:70 (MF: WWF, SF: WWF and MF: SF: WWF) and later used to make cookies. Chemical, rheological properties of the composite flours and sensory characteristics of cookies made from the above combinations were determined. The results of the proximate composition showed that the T3 possesses highest percentage of protein (14.80%), crude fiber (3.19%) and ash (1.79%) while T6 contain maximum value of moisture (10.10%), crude fat (2.268%) and T0 showed maximum NFE (72.09%). Farinogram properties such as dough water absorption, dough development time (DDT), departure time and stability decreased as the amount of substituted sorghum and maize increased whereas arrival time increased. Statistical results revealed that the addition of sorghum, maize and a combination of these whole flours have highly significant effect ($p<0.01$) on the sensory characteristics of cookies.

Keywords: composite flours, rheological characters, proximate composition, cookies, sensory evaluation

1. Introduction

Composite flour refers to the mixture of different concentrations of non-wheat flours from cereals, legumes, roots and tubers with wheat flour or can be a mixture of flours other than wheat flour [26]. Composite flours are recently manufactured not only to improve the desired functional properties of end product based on them but also to improve nutritional composition [37]. Cereal substitution to wheat is an economical step as well the deficiencies of wheat flour and its nutrients can be overcome by other cereal substitution [27].

Cereals are edible seeds belonging to the Gramineae (Grass) family [7]. Cereal grains are used as staple food in many countries and are important source of energy. They possess more than 70% of daily energy requirement [11]. Annual world cereal production is over 132 million tones. Wheat and maize are declared as major grains while sorghum as minor grains on basis of their global consumption [33]. Good nutritional value of cereals concerns with their proteins, carbohydrates and fiber contents and appreciable amounts of vitamins and minerals [17].

Corresponding author: *e-mail:* arshadfst@yahoo.com

Wheat is the staple food and economical means of calories and proteins for masses of Pakistan providing almost 341kcal/100g of wheat [34]. In baking industry wheat is preferred and most commonly used because of its unique rheological properties imparting positive effect on baking quality [35]. Whole meal flour production is the procedure mostly adapted during milling of wheat in Pakistan [6]. Nutritionally wheat contains 78.10% carbohydrates, 14.70% proteins, 5.1% fats and 2.10% minerals [21]. Wheat also constitutes considerable amounts of iron and zinc along with vitamins and sugars [4].However, single cereal diet is mostly lacking trace minerals and vitamins [30]. Moreover, wheat and wheat products contains lesser amount of proteins than required and lacks certain amino acids as lysine and tryptophan [18]. This can be a cause of malnutrition, food insecurity and deficiency of micronutrients [9]. Phytate contents in wheat are 0.3% in wheat meal and 5% in bran [25]. These phytate contents cause unavailability of certain nutrients as iron leading to iron deficiency anemia [8].

Sorghum and maize are ranked fifthand third respectively [19,22]. Annual production of sorghum is 0.13 million tons under the area of 0.21 million hectares in Pakistan in the year 2011-12 [14]. Sorghum is used for production of bread, porridges, tortillas, gruel couscous, alcoholic and non-alcoholic beverages [20]. Endosperm of sorghum grain is rich source of starch, protein, vitamin B-complex respectively. Bran of sorghum is excellent source of fiber, containing lesser amounts of ash and proteins. Phytochemicals as tannins anthocyanin's phenolic compounds phytosteroles etc. are important health maintaining contents of sorghum flour [16]. Composite flour's glycemic index will be reduced by increasing the levels of sorghum flour and it will be effective for patients of hypertension, diabetes and heart diseases [32].

Annual production of maize is 0.42 million on an area of 0.10 million hectares in Pakistan in the year 2011-2012 [14]. Fatty acid content and tocopherol of whole maize flour are well known for flavor and are important in regulating increased blood pressure, cholesterol levels and cardiovascular diseases as atherosclerosis [31].

Maize germ is a rich source of lysine and exceeds the double amount of lysine in wheat flour [36]. Hence, its substitution will reduce protein malnutrition. Only 35% of maize production is used in the form of chapattis/roti in the country while higher production percentages go for animal feeding. Other maize uses in Pakistan include edible oil from maize germ, starch, maize meal, corn flakes, grits and xylose and furfural type chemicals from maize [13]. Whole maize substitution with wheat flour can be an important step for successful energy and most of nutrient requirements of common masses of Pakistan. Moreover, increased nutritional contents concerning fat constituents may make the shelf life of composite flour questionable [23]. Present research was conducted to increase the nutritional value and to determine the rheological changes after blending and evaluate the sensory properties of cookies made from composite flour.

2. Material and methods

Procurement of Raw Material. Sorghum, maize and wheat varieties were procured from Wheat Research Institute, Ayub Agriculture Research Institute (AARI), Faisalabad and other materials were purchased from the local market.

Primary Treatment of Raw Materials. The cleaning of sorghum, maize and wheat grains was performed manually to remove damaged seeds, dust particles, seeds of other grains/crops and other impurities such as metals and weeds.

Preparation of Whole Flours. Whole flours of sorghum, maize and wheat grains were prepared by grinding these grains through UDY cyclone mill (mesh size 20mm).

Rheological studies. *α-amylase activity*.The amylase activity of the whole wheat flour and composite flours were studied through falling number. Falling numbers were determined using Pertin Falling Number Apparatus 1900 (Pertin Instruments AB, SE 1405, Huddinge, Sweden) by following the method No. 56-81 as described in AACC, 2000 [1]. 7 g of flour was taken into dry FN tube. 25 ml water was added at 22±2°C. Rubber stopper was inserted and tube was shaken in upright position for 30 times up and down until mixed. Viscometer stirrer was used to scrape down slurry coating upper part of tube, and all slurry scraped from stopper. Tube and viscometer stirrer were placed into water bath after mixing.At the end of test, time was recorded in seconds. FNs were calculated using following formula:

FN (14% moisture basis) = FN as is x (100-14) / (100 - moisture of sample in %)

Table.1. Percentage composition of composite flours

Sample	Wheat Flour (%)	Sorghum Flour (%)	Maize Flour (%)
T_0	100	-	-
T_1	90	10	-
T_2	80	20	-
T_3	70	30	-
T_4	90	-	10
T_5	80	-	20
T_6	70	-	30
T_7	70	15	15

T_0 100% WWF **T_4 10%WMF + 90% WWF**
T_1 10% WSF + 90% WWF **T_5 20%WMF + 80% WWF**
T_2 20% WSF + 80% WWF **T_6 30%WMF + 70% WWF**
T_3 30% WSF + 70% WWF **T_7 15%WMF + 15% WSF + 70% WWF**
WWF (Whole wheat flour) WSF (Whole sorghum flour) WMF (Whole maize flour)

Table 2. Ingredients for cookies production

Ingredients	Quantity
Composite flour	500.0g
Sugar	250.0g
Shortening	250.0g
Egg	2
Sodium Bicarbonate	8.0g

Farinographic studies. Rheological characteristics of composite flour samples such as water absorption, dough stability, dough development time, arrival time and departure time of the composite flours were measured using the Brabender Farinograph (C. W. Brabender, Duisburg, Germany) according to the standard method of AACC (2000) [1], Method No. 54-21 for the determination of the quality characteristics of composite flour samples. The instrument automatically determined the amount of flour to be poured into the mixer of the farinograph based on the moisture content of the flour samples. The farinograph was equipped with a 300 g capacity mixer. Mixing was carried out for 20 minutes. Immediately when the mixing started, the computer automatically started to plot the graph.

Sensory evaluation of cookies. The subjective evaluation of cookies was carried out for the external sensory characteristics. Cookies were evaluated for color, appearance, flavor, taste, crispiness, and overall acceptability. Judgments were made through rating products on a 9 point Hedonic Scale with corresponding descriptive terms ranging from 9 "like extremely" to 1 "dislike extremely", according to the method described by Meilgard *et al.*, 2007 [24] to find out the most suitable treatment for cookies production.

Statistical analysis. Statistical analyses were performed by using Minitab statistical software version 16 (Minitab Inc., State College, PA, USA) and by using two way analyses of variance (ANOVA) and LSD multiple comparison test.

3. Results and discussions

Proximate Composition of Composite Flours.The results of analysis proximate attributes of composite flours are presented in Table 3**.** The results presented in Table revealed that substitution levels showed significant ($p<0.05$) effects on moisture content of composite flours. The highest value was found in T_6 was (10.10%) and lowest in T_3 was (8.90%).

The gradual decrease in moisture contents of treatments T_1 to T_3 might be due to lower moisture contents in sorghum flour as compared to whole wheat flour and the gradual increase of moisture contents from T_4 to T_7 might be due to higher moisture content in whole maize flour with respect to whole wheat flour. Moreover, higher amounts of bran decrease moisture content in flours [40]. Results indicated that blending level given highly significant difference ($p<0.01$) on the protein content of the composite flours. Highest protein content were found in T_3 while lowest protein content were found to be in T_6 as 14.04- 13.23%. Results of present study are supported by the results of Yaseen *et al*., (2010) [38].

The statistical results presented in Table3 indicated that the crude fat contents showed highly significant affects ($p<0.01$) by the addition of whole sorghum and whole maize flour in whole wheat flour.. The highest significant value of crude fat content was found in T_6 (2.268%) in which whole wheat flour was supplemented at a level of 30% substitution of whole maize flour. The lowest fat content was found in T_0 (1.50). Maize flour substitution increased more fat content compared to sorghum substitution. Results did not matched with the findings of Okpala and Okoli (2011) [26]. This may be due to the fact that they blended sorghum flour with cocoyam and pigeon pea flours. Highest significant value crude fiber content was found in T_3 (3.19) having 30% sorghum substitution and the lowest value was observed in T_0 (1.73%). Whole sorghum flour substitution increased more fiber content as compared to whole maize flour. Results are in accordance with the results of Giwa and Victor (2010) [15]. The results indicated that ash contents showed highly significant difference ($p<0.01$) among all treatments of composite flours. T_3 possessed the maximum ash content as 1.79% which is 30% whole sorghum flour substituted treatment. Lowered significant value was observed in T_0 (1.28%). Whole sorghum flour substitution increased more ash content compared to whole maize substitution. Results found matching with the observation of Adebowale (2012) [2]. These results revealed that substitution levels showed significant effect ($p<0.05$) on NFE of composite flours. These results indicated that the NFE gradually decreased with increase in blending ratio of whole sorghum and whole maize flours. The highest significant value related to NFE was found in T_0 (72.09%) and lowest in T_3 (69.45%).

Functional characteristics of composite flour. *Wet and Dry Gluten*. Data regarding mean values of wet and dry gluten content of cereal flour mixtures have been explicated in Tables 5. Maximum mean value for wet and dry gluten content was found to be of whole wheat flour as 32.69 and 12.03 respectively, which were decreased with increase in substitution level of whole flours of other two cereals with minimum levels in T_3 and T_7. Mean values for wet and dry gluten content of sorghum substitution ranged from 29.10-22.62 and 9.70-7.54 respectively, while those of maize substitution included as 29.18-24.67 and 9.65-7.21 respectively. Results for blending all three cereals were recorded to be 22.68 and 7.42 for wet and dry gluten respectively. The results found similarity with the observations of Dhingra and Jood (2004) [10] who observed mean wet and dry gluten contents of 30.6 and 10.3% respectively during bread preparation from soybean and barely supplementation with wheat flour.

Rheological Studies. *α-amylase Activity of composite flours***.** The statistics regarding falling number of different treatments of composite flours has been depicted in the Table 4.These results evidently show highly significant affect ($p<0.01$) by addition of flours of both the cereals i.e. sorghum and maize. The highest value related to falling number was found in T_0 (456 sec) and the lowest for T_3 (315 sec). In general the results exposed that the falling number decreased with an increase in the substitution level of both sorghum and maize whole flours. The findings are in close relevance with the observations of Ali et al. (2000) [5], who found the falling number values of wheat-cassava composite flours without malt addition ranged from 581-484.

Farinographic studies. The results of analysis farinographic study of composite flours are presented in Table 4. It is clear from the Table 4 water absorption was highly significantly affected ($p<0.01$) by the addition of whole sorghum and maize flour. Value for water absorption of T_0 (66.1) was highest and the lowest for T_3 (59.2). The results clearly depict decreasing pattern with increase in replacing level of both sorghum and maize flour. The outcomes are close relevant to the observations of Yousif *et al.* (2012) [39] who found an increased level of water absorption in sorghum flour while studying the effect of sorghum flour on flat bread. The results show that the arrival time increased with increasing level of substituting flours. The results are close to the findings of Yaseen *et al.* (2010) [38] who observed farinograph arrival time variation from 2-4minby the substitution of maize flour in to bread flour without the addition of hydrocolloids.

DDT and Departure time was highly significantly affected ($p<0.01$) by the addition of the two cereal flours in the composition of wheat flour. The highest value (5.9min) was found in T_0 and DDT decreased with increasing the level of whole sorghum and maize flour. The results shows that DT decreased with increasing the levels of sorghum and maize flours. The results are close relevant to the findings of Dhingra and Jood (2004) [10]. The results show that the dough stability decreased with increasing the level of substitution. The results obtained are in close relevance with the findings of El-Khalifa & El-Tinay (2002) [12] who found the similar decreasing pattern with increase in sorghum and maize flour replacement levels.

Table 3. Effect of different treatments on proximate composition of composite flour

Treatments	Moisture%	Fat%	Protein%	Fiber%	NFE%	Ash%
T_0	9.50 d	1.50 f	13.90d	1.73 e	72.09 a	1.28 e
T_1	9.30 e	1.62 e	14.20 c	2.21d	71.19 de	1.48 c
T_2	9.10 f	1.74 d	14.50b	2.71b	70.31 f	1.64 b
T_3	8.90 g	1.87 c	14.80a	3.19 a	69.45 g	1.79 a
T_4	9.70 c	1.75 d	13.30f	1.66 e	71.90 ab	1.38 d
T_5	9.90 b	2.03 b	12.67g	2.22 d	71.68 bc	1.50 c
T_6	10.1 a	2.27 a	12.09 h	2.50 c	71.42 cd	1.62 b
T_7	9.10 f	2.02 b	13.50 e	2.85 b	71.04 e	1.49 c

Note: All values are mean of three readings

T_0 100% WWF **T_4 10%WMF + 90% WWF**
T_1 10% WSF + 90% WWF **T_5 20%WMF + 80% WWF**
T_2 20% WSF + 80% WWF **T_6 30%WMF + 70% WWF**
T_3 30% WSF + 70% WWF **T_7 15%WMF + 15% WSF + 70% WWF**
WWF (Whole wheat flour) WSF (Whole sorghum flour) WMF (Whole maize flour)

Table 4. Effect of different treatments on Rheological parameters of composite flour

Treatments	Water Absorption	Arrival Time	Dough Development Time(min)	Departure Time	Dough Stability (min)	Falling Number
T_0	66.0 a	1.53 e	5.83 a	8.86 a	6.0 a	454.33 a
T_1	62.9 d	1.82 cd	4.50 b	8.43 bc	5.2 c	398.67 ab
T_2	60.7 f	2.11 b	3.20 c	8.32 cd	4.4 e	363.67 bc
T_3	58.7 g	2.37 a	2.43 d	8.07 d	3.5 g	305.33 ab
T_4	65.0 ab	1.76 de	4.20 b	8.73 a	5.5 b	443.33 c
T_5	64.0 bc	2.01 bcd	2.50 d	8.67 ab	4.6 d	438.33 d
T_6	63.0 cd	2.23 ab	1.50 e	8.59 abc	3.7 f	412.00 a
T_7	61.8 e	2.06 bc	3.00 c	8.63 ab	4.5 de	428.67 e

Note: All values are mean of three readings

T_0 100% WWF **T_4 10%WMF + 90% WWF**
T_1 10% WSF + 90% WWF **T_5 20%WMF + 80% WWF**
T_2 20% WSF + 80% WWF **T_6 30%WMF + 70% WWF**
T_3 30% WSF + 70% WWF **T_7 15%WMF + 15% WSF + 70% WWF**
WWF (Whole wheat flour) WSF (Whole sorghum flour) WMF (Whole maize flour)

Table 5. Effect of different treatments on Gluten content of composite flour

Treatments	Wet Gluten %	Dry Gluten%
T_0	32.72 a	12.0 a
T_1	29.15 b	9.71 b
T_2	25.86 c	7.64 e
T_3	22.64 e	7.43 g
T_4	29.15 b	9.66 c
T_5	25.86 c	8.54 d
T_6	22.66 e	7.22 h
T_7	24.64 d	7.52 f

Note: All values are mean of three readings

T_0 100% WWF | **T_4 10%WMF + 90% WWF**
T_1 10% WSF + 90% WWF | **T_5 20%WMF + 80% WWF**
T_2 20% WSF + 80% WWF | **T_6 30%WMF + 70% WWF**
T_3 30% WSF + 70% WWF | **T_7 15%WMF + 15% WSF + 70% WWF**
WWF (Whole wheat flour) WSF (Whole sorghum flour) WMF (Whole maize flour)

Table 6. Effect of different treatments on various sensory attributes of cookies prepared from composite flour

Treatments	Color	Flavor	Taste	Crispiness	Overall Acceptability
T_0	7.50 ab	7.50 ab	7.50 b	7.13 c	7.75 ab
T_1	7.30 bc	7.00 bc	7.13 c	6.87 c	7.13 c
T_2	7.00 c	6.63 cd	7.13 c	6.50 d	7.03 c
T_3	6.00 d	6.25 d	6.25 d	6.25 d	6.63 d
T_4	7.50 ab	7.13 abc	7.55 b	7.87 b	7.50 b
T_5	7.63 ab	7.05 abc	7.60 b	8.00 ab	7.60 b
T_6	7.70 a	7.00 bc	7.70 ab	8.25 a	8.00 a
T_7	7.75 a	7.65 a	7.87 a	8.25 a	8.00 a

Note: All values are mean of three readings

T_0 100% WWF | **T_4 10%WMF + 90% WWF**
T_1 10% WSF + 90% WWF | **T_5 20%WMF + 80% WWF**
T_2 20% WSF + 80% WWF | **T_6 30%WMF + 70% WWF**
T_3 30% WSF + 70% WWF | **T_7 15%WMF + 15% WSF + 70% WWF**
WWF (Whole wheat flour) WSF (Whole sorghum flour) WMF (Whole maize flour)

4. Conclusions

The chemical analysis of different flour and their acceptable blends revealed that blending of cereals significantly increased the fat, fiber and ash percentages with the substitutions of both cereals. Protein contents were increased with whole sorghum and whole wheat blends but this protein effect was negative in case of whole maize substitution. Whole maize flour substitution affected rheological properties of composite flours but showed slightly lessened affects in relevance to sorghum flour substitution. On the basis of present study it was concluded that composite flour from different cereals can be prepared. These composite flours will have improved nutritional value and health benefits. This can be an important step at commercial level regarding health improvement of masses of Pakistan especially childhood groups with cookies as end product.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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