Physical and sensory characteristics of sugar cookies containing mixtures of wheat, fonio (*Digitaria exilis*) and cowpea (*Vigna unguiculata*) flours

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Summary White fonio (*Digitaria exilis*) and California blackeye cowpea (*Vigna unguiculata*) flours were used in sugar cookie preparation. Formulations were: (1) 100% wheat, (2) 50% wheat/50% fonio, (3) 50% wheat/50% cowpea, (4) 33% wheat/33% fonio/33% cowpea, (5) 25% wheat/75% fonio, (6) 25% wheat/50% fonio/25% cowpea, (7) 75% fonio/25% cowpea and (8) 50% fonio/50% cowpea. The 100% wheat cookies had the greatest spread ratio (5.86) and the 75% wheat/25% cowpea the least (4.39). The 50% fonio/50% cowpea cookies required the most force (720.3 N) to shear and the 50% wheat/50% fonio the least (399.4 N). The 100% wheat and the 50% wheat/50% cowpea cookies had the lightest colour and the 25% wheat/75% fonio the darkest. Sensory panel assessments of appearance, colour and texture were not affected by component flours. Cookies containing 100% wheat or 50% wheat /50% fonio received the highest hedonic ratings for flavour (7.1 and 6.7, respectively) and overall acceptability (6.9 and 6.5, respectively). All other formulations were unacceptable.

Keywords Acceptability, biscuits, colour, spread, texture, weight.

Introduction

Fonio (*Digitaria exilis*), a relative of crabgrass, and cowpea (*Vigna unguiculata*), a legume, are indigenous to West Africa; both are well adapted to the climatic and geographical conditions in that region of the world where they are highly favoured foods. Fonio has been described as one of the world's best tasting and most nutritious cereals, being rich in methionine and cystine (National Research Council, 1996). Although considered to be a 'minor millet,' fonio is of vital importance in certain regions of Africa where it produces relatively high yields (500–800 kg ha^{-1}) in spite of poor soil conditions and low or inconsistent rainfall (Jideani *et al*., 1994). Countries in which fonio is produced, in decreasing order, are Guinea, Nigeria, Mali, Burkina Faso, Ivory Coast and Niger (Dendy & Dobraszczyk, 2001). Fonio is a caryopsis type seed (McDonough *et al*., 2000) that is extremely small (about 1.0 mm long and 0.75 mm wide, 0.5 mg per 1000 kernels) and contains, in addition to carbohydrate, 8.2% protein, 2.1% fat, 0.4% fibre and 1.4% ash (Jideani & Akingbala, 1993; Irving & Jideani, 1997). Minimal processing is recommended for this grain because of its small size and location of constituents (Irving & Jideani, 1997).

Cowpea, the most important food legume in West Africa, is grown in the US as a fresh, horticultural crop and for processing (canning and freezing); there is also an extensive dry seed market (Fery, 1985). Cowpea contains substantial quantities of lysine and, when blended with cereal grains, gives mixtures with complementary amino acid profiles and improved protein quality (Bressani, 1985).

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Although bread is considered as the most universal of all bakery products, its large loaf volume and fine, even texture require formation of a well developed, elastic dough structure. An essential element in this process is gluten provided by flour milled from hard wheat (about 12% protein). In countries where climatic conditions are unsuitable for wheat cultivation or where importation of wheat is banned, production of bread from 100% wheat flour is impractical. This situation has prompted efforts to find adequate substitutes for wheat and bakery product alternatives to yeast-raised bread (Eneche, 1999).

The concept of using composite flour is not new and has been the subject of numerous studies. An extensive review reported that acceptable wheat products can be made with as much as 20–40% substitution with purified starches, 10–30% rice flour, 5–20% cereal and root flours, or with 3–15% of proteinaceous flours (Fellers & Bean, 1988). Cookies (biscuits) have been suggested as a better use of composite flour than bread due to their ready-to-eat form, wide consumption, relatively long shelf-life and good eating quality (Tsen *et al*., 1973). Cookies with high sensory ratings have been produced from blends of millet/pigeon pea flour (Eneche, 1999), greengram, bengalgram, blackgram and wheat (Singh *et al*., 1993), raw rice and wheat (Singh *et al*., 1989), groundnut, cowpea and wheat (Singh, 1991), chickpea/wheat (Singh *et al*., 1991) and soybean, chickpea or lupine with wheat (Hegazy & Faheid, 1990). No reports of studies were found for combinations of fonio, cowpea and wheat. The objective of this study was to determine the cookie-making performance of blends of fonio, cowpea, and wheat flour and the effect of the blends on the physical characteristics and sensory quality of sugar cookies.

Materials and methods

Flours

Fonio seed was purchased in a local market in Burkina Faso. The seeds were pounded, winnowed, washed, steamed, dried, packaged in plastic bags, and then shipped to the USA for milling and use in this study. Whole seeds were milled to flour in a microjet ultracentrifugal mill (model ZM1, F. Kurt Retsch Gmbh & Co., KG, Haan, Germany) equipped with a 0.2-mm screen and operated at 10 000 r.p.m. California blackeye cowpeas were obtained from Kerman Warehouse, Kerman, CA, USA, decorticated and milled to flour as described by McWatters *et al*. (1993). Wheat flour (plain, all purpose) was purchased at a local supermarket in Griffin, GA, USA.

Proximate composition of flours

Moisture content was determined by drying 5-g samples overnight in a vacuum oven at 25 mmHg and 70 °C. Crude fat was determined on moisture-free samples (about 1 g) extracted overnight with petroleum ether in a Goldfisch apparatus. Protein content was determined on 0.5-g samples by a nitrogen analyser (model FP2000, LECO, St Joseph, MI, USA). Factors used to convert nitrogen content to protein values were 5.70 for wheat flour and 6.25 for cowpea and fonio flours. Ash content was determined by heating 2-g samples overnight in a muffle furnace at 525 °C. Measurements of all flour components were made in triplicate.

Cookie formula

The formula and method of preparation were as described by McWatters (1978). Ingredients purchased from a local supermarket in Griffin, Georgia, were: flour, 75.5 g; sugar (granulated, cane), 75.0 g; shortening (hydrogenated vegetable), 47.0 g; egg (whole, fresh), 24.0 g; cream of tartar, 1.6 g; baking soda, 1.0 g; cinnamon, 0.5 g; and salt, 0.4 g. After mixing, the dough was rolled between sheets of wax-coated freezer paper to a uniform thickness of 9 mm and cut to a diameter of 3.8 cm. Cookies were baked on aluminium sheets at 204 °C (± 14 °C) in a conventional electric oven, cooled, packaged in Ziploc® bags, and stored at room temperature until evaluated later the same week.

Eight formulations with the following flour components were used: (1) 100% wheat, (2) 50% wheat/50% fonio, (3) 50% wheat/50% cowpea, (4) 33% wheat/33% fonio/33% cowpea, (5) 25% wheat/75% fonio, (6) 25% wheat/50% fonio/25% cowpea, (7) 75% fonio/25% cowpea and (8) 50% fonio/50% cowpea. Two replications of each formulation were prepared.

Physical measurements

Two cookies from each batch of the two baking replications were weighed; their height and diameter were measured with a vernier caliper (Cole-Palmer Instrument Co., Vernon Hills, IL, USA). Spread ratio was expressed as diameter/height. The same cookies were used to obtain instrumental colour and texture measurements. A colorimeter (Minolta CR 200, Minolta Camera Co. Ltd, Osaka, Japan) with a D_{65} illuminant, 0° viewing angle, and a measuring area of 8-mm diameter was used. A standard yellow tile ($L^* = 79.56$, $a^* = -2.17$, $b^* = 22.98$) was used to calibrate the colorimeter for measurement of the top and bottom surfaces of each cookie. The mean values for L*, a* and b* measurements were determined, and these were used to calculate chroma $[(a^{*2} + b^{*2})^{1/2}]$ and hue angle $[\tan^{-1}(b^*/a^*)]$.

For texture measurement, the multiple-bladed Allo-Kramer Shear Press attachment was connected to a 500-kg load cell. The cell was attached to an Instron universal testing machine (Model 1122, Instron Corp., Canton, MA, USA). Crosshead and chart speeds were 50 mm min^{-1}. The maximum peak force (Newtons) from the force-deformation curve was recorded.

Sensory evaluation

A panel of twenty-six consumers was recruited from faculty, staff and students at the University of Georgia, Griffin Campus. This number of panellists is considered adequate for rough product screening and for evaluating acceptance and/or preference (Anonymous, 1981). Criteria for selection were that panellists were 18 years of age, were regular consumers of cookies and were not allergic to any food. When panellists arrived, they completed a consent form approved by the University of Georgia Institutional Review Board and received instructions on how to use the sensory booth signal lights to communicate with the server. Panellists were instructed to evaluate appearance and colour first and then to taste each sample to evaluate flavour, texture and overall liking. A 9-point hedonic scale with 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely was used. Panellists attended two sessions over a 2-day period; they evaluated four samples from replication 1 on the first day and four samples from replication 2 on the second day. Water and unsalted crackers were provided to panellists to cleanse their palates between samples and covered expectoration cups if they did not wish to swallow the samples. Samples were identified with 3-digit code numbers and presented monadically in a random sequence to the panellists. Panellists were also asked if they would buy the product if it were commercially available and how much they would be willing to pay (lower, same, or higher price) compared with similar commercial products. They were also asked to comment freely on the samples. Evaluation was conducted in a climate-controlled sensory evaluation laboratory equipped with individual partitioned booths illuminated with two 40-watt incandescent bulbs which provided 473 lux of light at the cookie surface.

Statistical analysis

Sensory and instrumental data were analysed using the General Linear Model (GLM) procedure. Mean values and frequencies were obtained using the Statistical Analysis System (SAS Institute, Inc., 1995). Significant mean values were separated using the Least Significant Difference (LSD) test.

Results and discussion

Observations during preparation were that all eight formulations had good dough handling characteristics. The doughs rolled and cut well; however, the 50% wheat/50% cowpea dough exuded some free oil. All formulations produced the typical cookie shape and top grain surface appearance (Fig. 1); formula 5 (25% wheat/75% fonio) had more and deeper cracks than the other formulas.

Proximate composition

The proximate composition of the flours used for cookie preparation is shown in Table 1. The wheat and fonio flours were essentially identical in composition. The major difference in the three flours was in protein content, with cowpea flour containing about three times that of wheat and

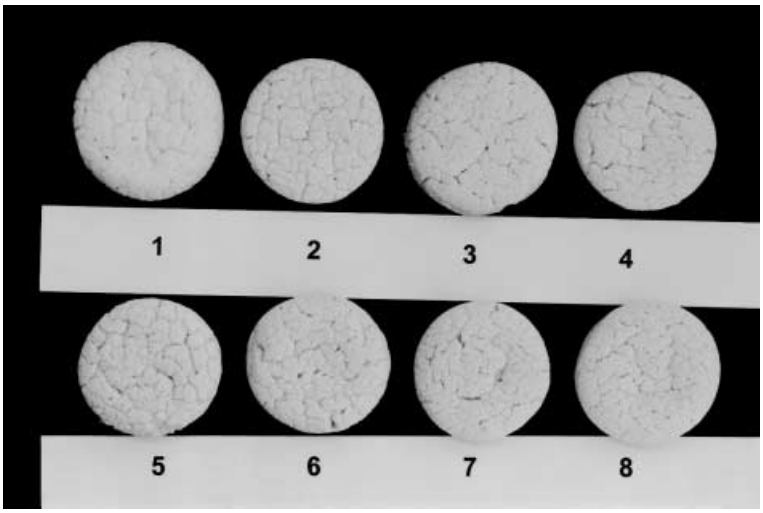

Figure 1 Sugar cookies prepared from (1) 100% wheat, (2) 50% wheat/50% fonio, (3) 50% wheat/50% cowpea, (4) 33% wheat/33% fonio/33% cowpea, (5) 25% wheat/75% fonio, (6) 25% wheat/50% fonio/25% cowpea, (7) 75% fonio/25% cowpea and (8) 50% fonio/50% cowpea.

Table 1 Proximate composition (%) of flours used in sugar cookie formulations

Flour	Moisture	Crude fat*	Protein*	Ash*	Carbohydrate*
Wheat, plain, all-purpose	10.6 (±0.07)†	0.7 (±0.83)	7.8 (±0.04)	0.8 (±0.84)	80.1
Fonio	10.2 (±0.05)	0.6 (±0.66)	7.5 (±0.06)	0.5 (±0.00)	81.2
Cowpea	9.3 (±0.05)	1.6 (±0.30)	22.9 (±0.03)	3.2 (±0.01)	63.0

*Wet weight basis. Carbohydrate content was determined by difference.
†Mean values of triplicate measurements (±s.d.).

fonio. The fat content of all three flours was low, ranging from 0.6 to 1.6%.

Physical characteristics

Weight, spread ratio and texture (peak force) of the cookies are shown in Table 2. Individual cookie weights ranged from 9.9 to 11.2 g with the 50% wheat/50% fonio being similar to the 100% wheat control. The heaviest cookie was produced by the 50% fonio/50% cowpea blend. The 100% wheat cookie had the highest spread ratio and the 75% fonio/25% cowpea the lowest. Cookies with 50% or more wheat (formulas 1–3) spread more than those containing 75% fonio (formulas 5 and 7). The blends which produced the softest cookie and required the least force to shear were 50% wheat/50% fonio and 25% wheat/75% fonio. Cookies made from 50% fonio/50% cowpea were the hardest, requiring the most force to shear. The high protein content of cowpea, which was in a native (undenatured) state in this study, and its interaction with fonio components during dough development and baking may have contributed to the harder texture of the 50% fonio/50% cowpea cookies. Flour

Table 2 Mean values for weight, spread ratio and texture (peak force) of baked sugar cookies*

Flour†	Weight (g)	Spread ratio (diameter/height)	Texture (peak force,N)
100% W	9.99 d	5.86 a	568.4 b
50% W, 50% F	9.90 d	5.21 b	399.4 c
50% W, 50% C	11.04 ab	5.43 b	634.6 ab
33% W, 33% F, 33% C	10.91 ab	4.70 cd	595.4 b
25% W, 75% F	10.19 cd	4.44 de	421.4 c
25% W, 50% F, 25% C	10.89 ab	4.78 c	602.7 ab
75% F, 25% C	10.64 bc	4.39 e	548.8 b
50% F, 50% C	11.18 a	4.82 c	720.3 a
Pr > F	0.0001	0.0001	0.0002

*Values in a column not followed by the same letter are significantly different ($P \leq 0.05$).
†W = wheat, F = fonio, C = cowpea.

Table 3 Mean values for colour measurements of sugar cookies containing varying levels of wheat, fonio and cowpea flours*

Cookie Surface	Flour†	L*	a*	b*	Chroma	Hue angle
Top	100% W	74.3 a	0.4	26.6 b	26.6 b	89.1 a
	50% W, 50% F	69.1 b	0.9	23.6 c	23.6 c	87.8 ab
	50% W, 50% C	73.4 a	0.6	29.6 a	29.6 a	88.8 a
	33% W, 33% F, 33% C	69.7 b	0.3	24.5 c	24.5 c	89.2 a
	25% W, 75% F	65.9 c	0.8	21.4 d	21.5 d	87.9 ab
	25% W, 50% F, 25% C	68.9 b	0.6	23.9 c	23.9 c	88.6 a
	75% F, 25% C	63.2 d	1.1	19.6 e	19.6 e	86.5 b
	50% F, 50% C	68.7 b	0.2	24.7 bc	24.7 c	89.5 a
	Pr > F	0.0001	0.1903	0.0001	0.0001	0.0351
Bottom	100% W	45.7	14.4 cd	41.2 abc	43.6 abc	70.7 ab
	50% W, 50% F	47.9	12.7 de	37.8 bc	39.9 bc	71.5 a
	50% W, 50% C	42.8	18.0 a	44.2 a	47.8 a	67.9 bc
	33% W, 33% F, 33% C	43.1	15.1 bc	39.2 abc	42.0 abc	68.9 ab
	25% W, 75% F	47.5	11.6 e	36.2 cd	38.0 cd	72.2 a
	25% W, 50% F, 25% C	44.1	14.3 cd	41.1 abc	43.5 abc	70.7 ab
	75% F, 25% C	41.7	13.3 cde	30.5 d	33.4 d	65.0 c
	50% F, 50% C	45.2	16.6 ab	42.8 ab	45.9 ab	68.8 ab
	Pr > F	0.1453	0.0001	0.0046	0.0024	0.0066

For each cookie surface, values in a column not followed by the same letter are significantly different ($P \leq 0.05$). L = lightness (0 = black, 100 = white), +a = redness, +b = yellowness, chroma = $(a^{*2} + b^{*2})^{1/2}$, hue angle = $\tan^{-1}$ (b*/a*).
†W = wheat, F = fonio, C = cowpea.

moisture content apparently was not responsible for this characteristic as it was essentially the same for all three flours (Table 1).

Both top and bottom surface colour of the cookies was influenced by the flour ingredients (Table 3). For the top surface, the 100% wheat and the 50% wheat/50% cowpea cookies had the lightest (highest L* value) colour and the 75% fonio/25% cowpea the darkest. Cookies with the most intense or saturated (highest chroma) top surface colour were produced by the 50% wheat/50% cowpea mixture; the 75% fonio/25% cowpea cookie had the least saturated top surface colour. Chroma differences were due to the yellowness (b* values) of the cookie. All the formulations produced cookies with top surface hue angles close to 90, indicating that their colour was more yellow (hue angle = 90) than orange (hue angle = 45) or brown (hue angle = 40–75). All the mixtures except the 75% fonio/25% cowpea produced cookies with top surface hues similar to the 100% wheat control.

For the bottom surface colour, the 50% wheat/50% cowpea cookie (formula 3) was more red (highest a*), more yellow (highest b*) and more saturated (highest chroma) than the other formulations. The bottom surface of the 75% fonio/25% cowpea cookie was less yellow, less saturated and had a lower hue angle than the other formulations. Not surprisingly, the bottom surface colours overall were darker, more red, more yellow, more saturated and more of a browner hue than the top surfaces.

Sensory evaluation

Sensory attributes of appearance, colour and texture of cookies were not affected by the component flours (Table 4). Cookies made with 100% wheat or 50% wheat/50% fonio received the highest hedonic ratings for flavour (7.1 and 6.7, respectively) and overall acceptability (6.9 and 6.5, respectively). All other formulations received flavour ratings (4.8–5.9) and overall acceptability ratings (4.9–5.5) below 6 (like slightly) and were therefore unacceptable. Panellists described the cookies containing 33 or 50% cowpea flour as having an aftertaste and a beany, nutty, or fishy flavour. This implies that some type of preliminary heat treatment is warranted to produce a blander flavoured cowpea flour than the unheated flour used in this study. Steaming cowpea meal for

Table 4 Mean sensory ratings for consumer acceptance of sugar cookies containing varying levels of wheat, fonio and cowpea flours*

Flour†	Appearance	Colour	Flavour	Texture	Overall
100% W	6.8	6.8	7.1 a	6.9	6.9 a
50% W, 50% F	6.3	6.3	6.7 ab	6.7	6.5 a
50% W, 50% C	6.8	7.0	4.8 d	6.4	5.2 b
33% W, 33% F, 33% C	6.5	6.2	4.8 d	5.8	5.0 b
25% W, 75% F	6.1	5.9	5.9 bc	5.7	5.5 b
25% W, 50% F, 25% C	6.2	6.1	5.5 cd	6.0	5.2 b
75% F, 25% C	6.2	5.9	5.5 cd	5.9	5.4 b
50% F, 50% C	6.4	6.3	4.9 cd	5.9	4.9 b
Pr > F‡	0.5678	0.1441	0.0001	0.0756	0.0001

*A 9-point hedonic scale with 1 = dislike extremely and 9 = like extremely was used. Mean values in each column not followed by the same letter are significantly different as determined by Fisher's least significant difference (LSD) at $P < 0.05$.
†W = wheat, F = fonio, C = cowpea.
‡Probability > F.

Table 5 Percentage of the panellists who were willing to buy and amount to pay for sugar cookies containing varying levels of wheat, fonio and cowpea flours

		Price		
Flour*	Yes	Lower	Same	Higher
100% W	61.5	32.0	60.0	8.0
50% W, 50% F	57.7	44.0	48.0	8.0
50% W, 50% C	26.9	66.7	33.3	0
33% W, 33% F, 33% C	30.8	68.0	32.0	0
25% W, 75% F	38.5	60.0	40.0	0
25% W, 50% F, 25% C	34.6	69.6	30.4	0
75% F, 25% C	34.6	66.7	33.3	0
50% F, 50% C	26.9	69.6	30.4	0

*W = wheat, F = fonio, C = cowpea.

30 min at 100 °C was found to be effective in improving the aroma and flavour quality of defatted peanut, soybean, pecan and cowpea meals used as extenders in ground beef patties (McWatters & Heaton, 1979). Cookies containing 50% or more fonio flour were frequently described as being crumbly and powdery.

Cookies which panellists would be most willing to buy were those made from 100% wheat and 50% wheat/50% fonio flour (Table 5). These were the formulations which received the highest hedonic ratings for flavour and overall liking. Most of the panellists (92%) were more willing to pay the same or a lower price for these two formulations than a higher price (8%). The remaining six formulations were less likely to be purchased and at a lower price than similar commercial products; none of the consumers were willing to pay a higher price for any of these. Thus, like/dislike of the sensory quality of the cookies from the eight formulations was reflected in the purchase intent exhibited by the panellists.

Although no reports were found in the literature about the cookie-making quality of combinations of wheat, fonio and cowpea flours, several studies had investigated cowpea/wheat blends. Vaidehi *et al.* (1985) reported that 40% malted (germinated) cowpea powder blended with 60% maida (finely milled wheat) flour had satisfactory baking performance and produced cookies that closely resembled the 100% wheat control in appearance and eating quality. This mixture spread more during baking and had 2% more protein than the control. Mustafa *et al.* (1986) reported similar findings when cowpea isolate was used to raise the protein content of wheat flour from 9.2 to 15%. Cookies produced from this mixture had a higher spread ratio than the 100% wheat control and received similar sensory ratings for taste, odour, colour and overall quality. Sharma *et al.* (1999) also noted improved spread ratio and top grain score as cowpea flour level in the wheat flour blend increased from 5 to 25%. However, overall acceptability decreased when the level of cowpea flour exceeded 15%. Singh (1991) reported that mixtures of cowpea and defatted peanut flours with wheat flour were more suitable for baking cookies than bread; acceptable cookies with

24.4% protein were produced with a mixture of 50% wheat flour, 35% defatted peanut flour and 15% cowpea flour. Findings from these studies show that cowpea flour, used within limits, is highly suitable for blending with wheat flour for cookie production.

Conclusions

Fonio flour can replace 50% of the wheat flour in a basic sugar cookie formulation without compromising sensory quality. This level of replacement would represent a significant reduction in dependency on wheat flour if cookies were manufactured in countries which import wheat. A higher level (75%) of fonio flour or blends of fonio with unheated (raw) cowpea flour produced unacceptable cookies, suggesting the need for alternative approaches (e.g. preliminary heat treatment) to improve the performance of these flours. The good dough-handling properties of all eight formulations showed that no dough conditioners or alterations in the manufacturing process would be needed to accommodate the use of these flours. However, mechanical methods for cleaning, decorticating and milling fonio seeds would be a necessity for improving the feasibility of using this unique millet in cookies or other types of bakery products. Future studies could investigate strategies to improve the sensory quality of cookies containing high levels of cowpea flour.

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