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Nutritional Characteristics of Rice (Oryza sativa L.) Composite Flours Obtained by Food Fortification

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ABSTRACT

High prevalence of protein-energy malnutrition among the vulnerable population, especially children has prompted research on fortification of common staple cereal foods such as rice. However, rice has inferior nutritional value compared to other popular cereals, such as maize, therefore limiting its full utilization. Its storage protein, glutelins, is not easily digested by monogastric animals; therefore, food to food fortification of rice flours provides protein nutritional compensation as well as improvement of other nutrients. This study was carried out to determine the proximate and mineral (Fe, Zn, Mg, Ca, P) composition of rice composite flours. Methodology: The blending ratios (rice: maize: sorghum: pumpkin: carrots: baobab: amaranth) used in the study were 70:0:0:7.5:7.5:5:10 (AT1), 45.5:24.5:0:7.5:7.5:5:10 (AT2), 35:35:0:7.5:7.5:5:10 (AT3), 23.3:23.3:23.3:7.5:7.5:5:10 (AT4) and 100% rice flour (AT5). Proximate analyses were performed according to Association of Official Analytical Chemist (AOAC) methods. Atomic absorption spectroscopy was used to determine the minerals. Data analysis was done using Analysis of Variance (ANOVA). Mean comparisons for treatments were done using Bonferroni tests and significance level was set at P≤0.05. Findings: Moisture content of the composite flours ranged from 10.87 to12.55% and was significantly different (p<0.05). Ash content was not significantly different (p<0.05) and ranged between 1.08 and 1.85%. The fat content ranged between 5.38 and 10.67%; with AT4 having the highest and AT5 having the least fat content. The carbohydrate content was significantly (p<0.05) different among the flour; ranging between 66.65 and 73.51%. Crude fibre ranged between 1.42 and -2.20%, whereas the protein content ranged from 6.88 to 7.73%. Iron content ranged between 0.06 and 0.08 mg/100g zinc ranged from 0.19 to 0.56 mg/100g. The phosphorus content ranged from 0.07 to 0.18 mg/100g with no significant (p<0.05) difference. The calcium content was significantly (p<0.05) different among the flours and ranged from 1.41 to 1.91 mg/100g. Conclusion: The results show that the flour composites have the potential to improve nutritional status of consumers. Thus, consumption of AT1, AT4 and AT5 composite flours with a protein content of 7.3%, 7.7% and 7.4% maybe recommended for children aged 6 - 59 months in order to prevent protein-energy malnutrition.

Keywords: rice flours, proximate, composites, value-added.
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I. Introduction

Rice (*Oryza sativa* L.) is a staple food for more than a third of the world's population [1], [2] especially in Africa [3], [4]. In Kenya, rice is currently the third most important staple cereal after maize and wheat [3] and for low income consumers, rice accounts for 3.9%-4.8% of total food expenditure compared to 13.5% and 9.7% for maize and wheat, respectively [5]. Rice consumption in Kenya keeps growing at 11% every year since independence and this is attributed to population growth, urbanization and change in consumer habits [3], [4], [6]. Currently, Kenya produces about 150,000 metric tons from about 25,000 hectares of land [7]. This meets only about 20% of the total demand as annual rice consumption is about 550,000 metric tons [6], [7]. However, rice has inferior nutritional value compared to other popular cereals such as maize, therefore limiting its full utilization [8]. This inferiority is partly because it is majorly composed of starch (approximately 80%–85%), 4%–10% protein, 1% lipid and 10% moisture [9]. Also, its storage protein, glutelins, is not easily digested by monogastric animals [10]. This has therefore necessitated food to food fortification of rice flours to improve on bioavailability of micronutrients as well as the protein quality [11]. Composites are mainly done with legumes which are rich in lysine, with a cereal that contains a relatively good concentration of sulphur-containing amino acids, resulting in protein nutritional compensation [12]. Rice is mostly consumed as cooked grains but can also be processed into flour and used to make various beneficial products since its gluten free, low in calcium and lacks most of the allergic proteins [1], [8], [13], [14]. Globally, rice is mainly used for production of noodles, sweets, and desserts [15]. It is also an excellent thickener for custards, gravies,

and sauces [16]. Rice flour is also used as thickening agent in refrigerated or frozen recipes since it inhibits liquid separation [11], [17]. Its low-allergenic properties also make it suitable for infants [8], [18]. Rice has other unique functional properties such as flavor carrying capability, hypo-allergenicity and bland flavor, making them desirable for use in value-adding products. Despite all these advantages, rice is deficient of some nutrients: it has weak functional proteins, 80% glutelin, which is not very soluble in water [13], [19]. To enhance rice production and hence boost food and nutrition security, Kenya's policy makers must understand the impediments that exist across the rice value chain and import process and explore the opportunities that may exist within the value chain such as value addition. This study was designed to determine the proximate and mineral characteristics of rice composite flours containing different proportions of a variety of other nutrient-rich foods.

II. Materials and Methods

A. Sample Acquisition

The raw materials were sourced from different parts of Kenya. Maize was obtained from Eldoret market located in the Rift Valley region of Kenya. Pale-red sorghum (E97) and pale cream amaranth grain were obtained from Busia and Bungoma, Western Kenya. Baobab powder was obtained from Mombasa and the sweet potato puree was obtained from Organi Limited in Homabay, Kenya. The rice used in the study was the Kenyan variety Mwea Pishori rice. The dried foodstuffs were stored at 25 ˚C and the potato puree was stored in a deep freezer at -20˚C. The cereals were washed and dried whereas the vegetable sources were pealed and blanched at 75 ˚C for 5 minutes [20], [21] before grating. They were then dried using Kleins Dehy-Tray (JUA Technologies International, USA) at 75℃ for 6 hours.

B. Preparation of Compositing Flours

Milling of the ingredients was individually done in a laboratory grinder (Bountiful International, USA) to obtain the flours. The flours were sieved, immediately packaged in airtight containers and stored in a cool and dry place at room temperatures (~25 ˚C) until use [20].

C. Formulation of Value-added Composites

Four composites (AT_1, AT_2, AT_3 and AT_4) were prepared with a variation in the rice, maize and sorghum cereals used. Composite AT_5 (100% rice flour) was used as the control (Table 1).

Table 1: Composition of Composite Flours

Ingredients	Composites (%)				
	AT_1	AT_2	AT_3	AT_4	AT_5
Rice	70	45.5	35	23.3	100
Maize	_	24.5	35	23.3	_
Sorghum	_	_	_	23.3	_
Pumpkin	7.5	7.5	7.5	7.5	_
Carrots	7.5	7.5	7.5	7.5	_
Baobab	5	5	5	5	_
Amaranth	10	10	10	10	_
Total	100	100	100	100	100

D. Reagents for Analysis

All the chemicals used for proximate and mineral analyses were of analytical grade from Sigma Chemicals Co. (St, Louis, MO, USA). These included n-hexane, sulphuric acid, nitric acid, sodium hydroxide, hydrogen peroxide, hydrochloric acid, boric acid, mix indicator and standards of minerals.

E. Proximate Analysis of Rice Composite Flours

Proximate analysis: ash, fats, moisture, crude fiber and protein content were performed according to Association of Official Analytical Chemist official methods; 923.03, 925.09, 978.10 and 979.09 [22]. Moisture content was determined by the oven method; protein content was determined by Kjeldahl method (nitrogen content × 6.25); fat content was determined by petroleum ether extraction; and crude fiber was determined by digesting defatted samples with diluted (1.25%) sulfuric acid solution for 30 mins at boiling point followed by digestion with 1.25% sodium hydroxide solution for the same 30 mins [12], [23], [24]. The carbohydrate content was determined as difference between 100 and total sum of the percentage of ash, moisture, fiber, fat and protein [25]. All analyses were performed in triplicates.

F. Mineral Analysis of Rice Composite Flours

Atomic absorption spectroscopy (AAS AA-7000, Shimadzu Cop. Japan) was used to determine the minerals; iron, zinc, calcium, phosphorus and magnesium. Approximately 2.0 g of flour composites were weighed and transferred into a digestion flask, to this 5.0 mL concentrated nitric acid was added [26]. The flasks were heated at 80-90 ºC for 2 h to digest. The temperature was then raised to 170-180 ºC and 3-5 mL of each of the hydrogen peroxide and sulphuric acid (concentrated) were added and heating continued until the material was completely digested [25]. The digest was then transferred to a 50 mL volumetric flask and the volume made up to the mark with deionized water. Primary standard solutions of Mg, Ca, Fe, P and Zn were prepared and diluted successively to obtain required series of solutions for construction of standard calibration curve [22].

G. Data Analysis

Data analysis was done using Analysis of Variance (ANOVA) with Stata♥ version 12. Mean comparisons for treatments were done using Bonferroni tests. Significance level was set at $P \leq 0.05$.

III. Results and Discussion

A. Proximate Composition

Results of proximate composition are presented in Table 2. Moisture content was significantly different ($p<0.05$) among the composites; with the lowest level (10.9%) being in AT5 and the highest (12.6%) in AT2. These values are similar those reported by [2], [27], [48]. However, the values are slightly higher than those reported by [14], [15], [28]-[30]. The high moisture level of AT2 could be attributed to the drying temperature used [31]. Composites, such as AT4 and AT5 that had low moisture content have

potential for long storage [11]. The significant difference observed in the moisture content of the flour composites may be attributed to temperature and duration of drying. The Moisture content of food is influenced by the type of food, food variety, and storage conditions [28]. Flours with moisture content above 14 percent are t often no stable at room temperature and may spoil easily and the relative high moisture content may reduce the shelf life of the composite flour: food materials, such as flour, containing more than 12% moisture have lesser storage stability than those with lower moisture content [32].

The ash content of the composite flours ranged between 1.08-1.85%, with no significant difference ($p<0.05$) among the sample composites. Composite AT3 had the highest ash content of 1.85% (Table 1) while composite AT5 had the least ash content of 1.08%. These results are close to those reported by [2], [15], [33]. The values are also similar to those reported by [16], [26], [28], [30]. The ash content of a food sample is indicative of the mineral elements present in the food sample [34]. Minerals are more concentrated in the bran and thus get lost during milling and polishing [42]. The low ash content observed in the other varieties may be due to the degree of milling/polishing.

The fat content obtained ranged between 5.38-10.67% with AT4 having the highest fat content and AT5 having the least fat content (Table 2). The values are close to the range reported by [15], but higher than those reported by [2]. There was observed significant difference in fat content ($p<0.05$) which could be attributed to the different proportions of sorghum used. Milling and polishing of rice removes the outer layer of the grain where most of the fats are concentrated [36].

Carbohydrate content ranged between 66.65-73.51% and statistical analysis showing significant difference ($p<0.05$). These values correspond closely to that reported by [2], [15], [16], [30], [33], [44], [48]. [2] reported carbohydrate content range between 74.20-79.41%, whereas [33] reported values ranging between 78.3% and 81.1%.

The range of values for crude fibre observed in this study was between 1.42-2.20% for the five rice flour composites (Table 2). These values are almost similar to 0.5 - 1.95% reported by [2]. [27] reported slightly lower crude fibre values ranging between 0.59 - 0.89% for different varieties of rice. [15] reported crude fibre range of 0.99-1.01%, which is slightly lower than the results of the present study. Statistical analysis did not reveal any significant difference ($p<0.05$) in the crude fibre values for the rice flour composites. Milling of rice during the production of polished rice generally decreases the fibre contents; hence the relatively low fibre in the imported brands [41]. The bran is particularly rich in dietary fibre and contains significant quantities of starch [47] which also contributes to the carbohydrate content of brown rice. The observed difference may be due to the fact that the imported rice brands are more polished than the local varieties. Percentage carbohydrate could also be influenced by other environmental factors under which rice is grown (soil type, crop management practices, rainfall, solar radiation, and growth temperature) [41].

The protein content of the rice flour composites ranged from 6.88–7.73% (Table 2). Composite AT3 had the lowest protein content (6.88%) while composite AT4 had the highest protein content, although statistical analysis showed no significant difference ($p<0.05$) in protein contents among the composites. These findings are in the range of values reported by [2], [15], [39], [44], [48]. However, these findings were higher than the findings reported by [34] a range of 5.10-5.30%. [38], [40] reported that deposition of protein in rice grains depends on plethora of interrelated metabolic pathways involved in uptake of N, Fe and Zn from soil, their transport to source tissues such as culms and leaves and mobilization and/or remobilization to developing grains. Each of these processes is governed by several genes and influenced by environmental factors such as soil type, drought, fertilizers application, genotype and environment interaction [37], [50].

TABLE 2: PROXIMATE COMPOSITION OF VALUE-ADDED RICE FLOUR COMPOSITES

Sample	%Composition					
	Moisture	Fat	Ash	Proteins	Fiber	Carbohydrate
AT1	12.00±0.26^{a}	8.00±0.98^{bd}	1.78±0.14^{a}	7.30±0.09^{a}	1.90±0.19^{a}	68.59±1.02^{a}
AT2	12.55±0.28^{b}	7.13±0.57^{a}	1.82±0.15^{a}	6.94±0.30^{a}	1.42±0.08^{a}	71.14±1.03^{bd}
AT3	12.13±0.19^{ab}	9.20±0.28^{c}	1.85±0.24^{a}	6.88±0.27^{a}	2.20±0.38^{a}	67.74±0.46^{ad}
AT4	11.87±0.13^{ac}	10.67±0.21^{a}	1.68±0.10^{a}	7.73±0.57^{a}	1.83±0.13^{a}	66.65±0.58^{a}
AT5	10.87±0.19^{a}	5.38±0.48^{abd}	1.08±0.22^{a}	7.38±1.07^{a}	1.78±0.18^{a}	73.51±1.06^{a}

Values are mean±standard deviations of triplicates. Values with different letter superscript in the same column are significantly different at ($p<0.05$) based on Bonferroni tests.

B. Mineral Composition

Table 3 shows the mineral content of five (5) of the rice flour composites. Iron content ranged between 0.06– 0.08 mg/100 g. Composites AT3 and AT5 had the least iron content while composites AT1 and AT4 had the highest iron content. There was no significant difference ($p<0.05$) in iron content of the composite flours (Table 2). The values of iron obtained were much higher than that reported by [2], [33], [35]. This low iron content may be due to milling that interfered with bran particularly rich in dietary minerals such as iron. The difference in iron content among the rice varieties may also be influenced by nitrogen application and soil quality [46].

The magnesium content of the flour composites ranged from 1.26-5.58 mg/100 g with a significant difference ($p<0.05$) (Table 3). These values are much lower than that reported by [2], [33]. The local intra varietal differences could be due to genetic factors or the mineral content of the soil on which they were grown [42]. In general, the more rice bran is removed from the grain during polishing, the more minerals are lost [41].

The zinc values obtained in this study ranged from 0.19-0.56 mg/100 g (Table 3). These values are slightly lower than earlier findings by [45] who found a range of 1.40 to 1.79 mg/100 g and 1.97 mg/100g reported by [49]. [2] reported a range of 1.05 to 2.9 mg/100 g, which is also slightly higher than the values in this present study. Phosphorus content of the rice flour composites ranged from 0.07-0.18 mg/100 g with no significant difference ($p<0.05$). The calcium content of the composites ranged from 1.41-1.91 mg/100 g with significant difference ($p<0.05$).

The chemical composition (nutrients) of rice grain varies considerably depending on factors like plant variety (breeds), environmental condition (i.e. location and season in which grown), fertilizer treatment, degree of milling, and condition of storage [43]. As with all natural foods, the precise nutritional composition of rice varies depends on the variety, soil conditions, environmental conditions and types of fertilizers.

TABLE 3: MINERAL COMPOSITION OF VALUE-ADDED RICE FLOUR COMPOSITES

Sample	Mineral elements (mg/100g)				
	Phosphorus	Zinc	Iron	Calcium	Magnesium
AT1	0.14 ± 0.01^{a}	0.56 ± 0.03^{ab}	0.08 ± 0.00^{a}	1.91 ± 0.08^{a}	3.20 ± 0.01^{a}
AT2	0.18 ± 0.10^{a}	0.22 ± 0.01^{a}	0.07 ± 0.01^{a}	1.41 ± 0.01^{b}	1.26 ± 0.02^{a}
AT3	0.14 ± 0.03^{a}	0.37 ± 0.04^{cd}	0.06 ± 0.01^{a}	1.57 ± 0.03^{bd}	2.97 ± 0.04^{b}
AT4	0.14 ± 0.01^{a}	0.36 ± 0.04^{c}	0.08 ± 0.01^{a}	1.45 ± 0.02^{bc}	3.36 ± 0.03^{a}
AT5	0.07 ± 0.02^{a}	0.19 ± 0.02^{e}	0.06 ± 0.01^{a}	1.64 ± 0.02^{c}	5.58 ± 0.23^{c}

Values are mean±standard deviations of triplicates. Values with different letter superscript in the same column are significantly different at ($p<0.05$) based on Bonferroni tests.

IV. CONCLUSION AND RECOMMENDATION

The results from the study show that food to food fortification approaches result into a nutrient enhanced rice composite flours which maybe suitable for both home and industrial applications. Therefore the study recommends a consumer acceptability study to evaluate consumer preference and acceptability. This shall lead to popularization and adaptability by the caregivers to enhance food and nutrition diversity and protein energy malnutrition prevalence reduction.

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