ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 21 No. 10
November 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2021; 21(10): 18965-18979 https://doi.org/10.18697/ajfand.105.21395

PROXIMATE COMPOSITION AND SENSORY CHARACTERISTICS OF REFRACTANCE WINDOW DRIED COWPEA COMPOSITE PORRIDGES

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ABSTRACT

Undernutrition is a major public health concern in Uganda. Locally available nutrient dense diets can help reduce the problem of undernutrition. Utilisation of cowpea leaf powder in preparing composite porridge blends depends on sensory acceptance of the consumers. A Nutrisurvey software was used to formulate two composite flour blends, namely maize and millet in a ratio 2:8 and cowpea-maize in a ratio of 1:9 to achieve the daily requirement of protein for children. The study developed a process for the production of composite cowpea flour from finger millet flour and maize flour and followed a one factor design in which maize flour (MF) and millet flour (MMF) was substituted with cowpea leaves flour (CPL). The composites were dried using refractance window drying technology. The proximate composition of the composite flours were determined using standard methods while sensory acceptability of porridges was rated on a five-point Likert scale using an untrained panel. Results indicated a significant ($p < 0.05$) increase in protein (10.9 to 13.4%), dietary fibre (11.01 to 13.0%) and lipids (4.71 to 5.3%) contents for cowpea-millet composite porridge. For cowpea-maize composite flour, a significant ($p < 0.05$) increase in protein (5.9 to 7.6%), dietary fibre (1.47 to 3.3%) and lipids (2.84 to 3.3%) was also observed. Sensory evaluation indicated that between the two composite porridges, the cowpea-millet porridge blend was significantly ($P \leq 0.05$) more appealing in terms of colour (3.61±0.8), aroma (2.96±0.2), taste (3.24±0.6), texture (3.62±0.6) and general acceptability (3.61±0.8) to the panellists than the cowpea-maize porridge blend. The cowpea-millet and cowpea-maize composite flours can contribute more than 100% of the recommended dietary allowance of protein and carbohydrate requirements for children aged 0-8 years. The study findings indicate that the cowpea-based composite flours have the potential to make a significant contribution to the improvement in the nutritional status of infants and children in developing countries.

Key words: Composite flours, Recommended Dietary Allowance (RDA), sensory attributes, refractance window drying (RWD)

INTRODUCTION

In Uganda, cowpea (*Vigna unguiculata* (L). Walp) is the fourth most consumed legume, after beans, groundnuts and soybeans [1], a crop with potential to create employment especially among women and the youth [2]. It is recommended to use locally available crops such as cowpeas, to sustainably address the high food and nutrition insecurity challenges in Uganda [3]. This would complement existing strategies such as fortification and supplementation by offering a sustainable and low cost way to reach people with poor access to health care and food systems [4]. Cowpea is a rich source of essential nutrients; vitamin C (70-203g/100g), carotenoids (32.74-36.55mg/100g), iron (66-75 mg/100g), calcium (17.1-39.87 mg/100g), zinc (5.22-12.91 mg/100g), proteins (28-42 g/100g), total essential amino acids (0.027-0.031 mg/100g) and crude fibre (10.09-25.51 g/100g) [4,6,7]. As a result of possessing considerably high nutrient content, cowpeas leafy vegetables have the potential to boost the nutrient content of less nutritious foods [8]. Within rural African settings, a number of dishes are served with cowpea leaves as an accompaniment to or as a side dish in order to have a balanced diet [9].

There is a growing trend in Uganda and the rest of Africa, to promote the use of composite flours developed using locally grown legumes and other cereals that are nutrient rich [10]. The quality of the products that are made from combinations of cereals and legumes, depend on the individual proportions of the composite constituents. Furthermore, the refractance window drying (RWD) technology has been documented by Nindo *et al.* [11] as a feasible drying technology for production of high-quality products. The RWD dryers are a superior alternative to conventional commercial dryers especially among small-scale processors in Africa. RWD dryers are mechanically simpler to operate, compared to commercial dryers and better in retaining nutrients due its faster drying of foods. The retained nutrients can go a long way in addressing the unacceptably high nutrition disorders in rural settings of Africa. It involves a thin film drying system having high heat and mass transfer rates that speed up the rate of drying at a comparatively lower temperature [11,12]. Additionally, RWD is a more reliable, efficient and cheaper drying method with better retention of the product's natural colour and aroma compared to conventional drying methods such as sun drying [12]. For the aforementioned reasons, cowpea leaves in Uganda would best be dried using the RWD technology. Previous work on composite cowpea leaves flours has been documented on nutritional and functional properties of composite cowpea flours and its blends with sorghum [13], African yam bean [14], peanut [15], *bambara* groundnuts [16], maize flour [17], wheat [18], and soy bean flour [19]. However, the functional and nutritional properties of products made from a combination of RWD dried cowpea leaf powder and other foods are not well documented. To effectively, advocate for production, preparation and consumption of composite flour of RWD dried cowpea leaves, blended with maize and millet flours, there is need to generate data on acceptability and nutrient composition of the composites.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 10 November 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

MATERIALS AND METHODS

Collection and preparation of raw materials

Cowpea leaf batches with stalks were procured from farmers in Budondo sub-county, Jinja district in eastern Uganda. The leaves were placed in an icebox and immediately transported to the Nutrition laboratory of Makerere University, Department of Food Technology and Nutrition in Kampala, Uganda. While at the laboratory, the leaves on the plant were removed from their stalks by hand, and thereafter sorted to remove wrinkled, bruised and bleached leaves. The leaves were then rinsed with clean running tap water to remove dirt and other foreign matter. The millet (*Eleusine coracana*) flour and maize (*Zea mays*) flour were purchased from Wandegeya market in Kampala City. Cowpea leaf powder was obtained after successfully drying the leafy vegetables using refractance window drying (RWD) technology at 95^{o}C for 1 hour for maximum nutrient retention. The RWD dryer (MCD Technologies, Inc. Tacoma, Washington, USA), was used to dry the fresh cowpea leaves. The dryer had a conveyer belt on which a thin layer of fresh cowpea leaves were placed. The conveyor rotated at a speed of 1.04 m/min, over the hot water at 95 °C beneath, transported the drying leaves through a cooling section, before the dried cowpea leaves were dropped into a container, at the end. Dried leaves were packed in vacuum polyethylene bags for further analysis.

Determination of optimum level of cowpea-millet and cowpea-maize flour incorporation

Nutri Survey linear programming software was used to guide the rationing of flour ingredients to produce the composite flours [20]. The nutrients optimised were protein, carbohydrates and dietary fat. The rationing was done to ensure that the formulation provided 100% of the daily recommended proteins intake (14g/day) in a single meal for infants aged between (6-12 months) and (20 g/day) children aged (1-8 years) [21,22]. The software recommendation ratios of 2:8 for cowpea-millet composite and 1:9 ratio for cowpea-maize composite, meeting the proteins requirements were adapted for this study.

Preparation of composite porridges

The cowpea-millet composite porridge was prepared by mixing 60 g (12 g of cowpea and 48 g of millet) of the composite flour, while the cowpea-maize porridge was produced by mixing 60 g (6 g of cowpea and 54 g of maize flour), with 150 ml of cold water in the saucepan. The mixture was heated to boiling point. About 25 g of sugar was added to the boiling porridge and stirred to dissolve the sugar. Hot water was added to the boiling porridge until it topped up to 1000 ml. The mixture was left to boil for 2-3 mins while stirring and then removed from the cooking stove to cool.

Sensory acceptability of the cowpea porridge blends

Sensory properties of the two porridge blends were assessed by 106 untrained female panellists drawn from communities of Kayunga district. About 30 ml of the samples were served warm following the recommended practices [10]. The ages of female panellists ranged from 13 to 60 years with majority falling in the range of reproductive age bracket. The untrained female panellists in this age bracket were preferred because their view would reflect the actual perception of the product by children. Each panellist was provided with drinking water to rinse the mouth after each taste. The sensory attributes of porridges that were assessed were colour, aroma, texture, taste and general appearance of the porridge combinations. A five-point Likert-scale ranging from 1= dislike very much, 2= dislike it, 3= neither like or dislike it, 4= like it, 5= like it very much was used for the assessment [10].

Proximate composition of the flours

Protein determination

Total crude protein content was determined using the Kjeldahl 984.13 method [23]. About 0.5 g each of the two porridges, were mixed with 10 ml of concentrated sulphuric acid and digested with a Kjeldahl digester (Model Bauchi 430). About 40 ml of water was added to the digest and distilled using a Kjeldahl distillation unit (Model unit B-316). Liberated ammonia was collected in 20 ml boric acid with bromocresol green and methyl red indicators and titrated against 0.04 N sulphuric acid (H_2SO4). Crude protein was determined by multiplying nitrogen content by a factor of 6.25.

Determination of carbohydrate

Carbohydrate content was determined by the phenol-sulphuric acid method [24]. One gram of the sample was mixed with 5 ml of 2.5 N hydrochloric acid (HCl) and boiled in a water bath for 3 hours to hydrolyse the sugars. After cooling, 100 ml of solid sodium carbonate was added until the effervescence stopped. The mixture was filtered and made up to the mark using distilled water in a 100 ml volumetric flask. Into a test tube, 5 ml of sample was pipetted and 1 m of 5% phenol solution added. After shaking well, 5 ml of concentrated sulfuric acid (96%) was added after which the mixture was vortexed and then left to stand for 10 minutes. Absorbance of the sample was read at 490 nm using a spectrophotometer (Spectroquant Pharo® 300, EU) [24]. A standard curve was developed using glucose standards of varying concentration (0.01 to 0.1 mg/ml). The total amount of carbohydrate in the sample derived from glucose standard graph was expressed as g/100g of the powdered cowpea leaves.

Lipid determination

The total lipid content was determined using the ether extraction method 920.39 [23]. Crude lipid was extracted from the two cowpea composite porridges using 5g for each sample of the extract in petroleum ether as a solvent and soxhlet extractor (Dijkstra Vereenigde BV, Lelystad, The Netherlands). After evaporation of the petroleum ether, the weight of the lipid obtained gave the crude lipid in the samples.

Ash determination

The inorganic matter (total ash) was determined using method 942.05 [23]. The organic matter of the two cowpea composite porridges was removed by heating them at 550°C overnight and the residue being the inorganic matter (ash).

$$\frac{\text{Weight of crucible and ash} - \text{weight of crucible}}{\text{Weight of crucible and sample} - \text{weight of crucible}} X\ 100$$

Dietary fiber determination

The total dietary fibre content was determined using the method 978.10 [23]. Five grams of the samples, were used to determine the fibre content by acid digestion, filtration and base digestion. The resulting residues were eventually ignited at 550°C in a muffle furnace. Crude fibre content was expressed as a percentage lost on ashing, compared to the initial weight.

Data analysis

All experimental samples were prepared in triplicate ready for analysis. Data were analysed using XLSTAT (version 2012.10.7.01 Addinsoft, Paris France), to generate the analysis of variance (ANOVA) and to determine variation between means of cowpea-millet and cowpea-maize based composite porridges for their nutrient composition, and sensory properties of the porridges prepared from the two composites flours. The nutrient contribution of an average daily consumption of the two composite cowpea porridges in the present study, to nutrient intake recommendations of infants aged 6-12 months and children aged of 1-8 years, were computed and expressed as a percentage of the recommended dietary allowances (RDA) [21, 25]. During the computation of contributions towards the RDAs, the digestibility and bioavailability of proteins and other nutrients were taken into consideration [21, 22]. The macronutrients (proteins, carbohydrates and fat) contributions were calculated based on total daily food intake estimations of children reported by Otten *et al* and Fungo *et al* [21,22], where infants aged 6 to 12 months and children aged 1 to 8 years in Uganda consume about 200g daily as reported by Kikafunda *et al.* [26]. Using these daily porridge intake estimates per individual, the potential contributions of the composite porridges on the daily nutrients requirements among children was calculated.

RESULTS AND DISCUSSION

Proximate composition of the composite porridges

The present study revealed that addition of cowpea flour to either millet or maize flours, remarkably improved the concentration of proteins, dietary fiber and fat in the composite porridges compared to the contents of these nutrients registered in porridges of only plain flour maize or millet (Table 1). The high nutrient content registered in the two composite porridge blends can be attributed to the optimal drying conditions of refractance window drying (RWD) technology. Leafy vegetables dried using RWD technology were exposed to temperatures of 95°C for a short time (approximately 10 minutes), with the final products retaining nutrients and maintaining good sensory qualities, such as colour and aroma [11, 27, 28]. For example, the protein contents of the two cowpea based composite flours significantly ($p<0.05$) increased from 10.96 g/100g in plain millet porridge to 13.4 g/100g in cowpea-millet composite porridge, and from 5.91 g/100g in plain maize porridge to 7.6 g/100g in cowpea-millet porridge. Then again, the dietary fiber contents significantly ($p<0.05$) increased from 11.01 g/100g in plain millet porridge to 12.5 g/100g in the composite cowpea-millet porridge. It was further observed that addition of millet and maize flours to the cowpea powder slightly improved the lipids and ash contents of both cowpea-millet and cowpea-maize composite flours.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 10 November 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

It has been reported elsewhere, that the blending of two or more plant-based food materials especially when flours of legumes are blended with cereal flours, remarkably increases the nutrient density of the resulting food product [29]. Therefore, the addition of RWD technology dried leaves of cowpea a legume, to the flours of cereals of millet and maize respectively, boosts the nutrient contents of the cowpea-based composite flours. Legumes including cowpeas generally contain higher nutrient content than cereals, especially the amino acid content [30]. Mariam [31] reported an increment in the protein content to 65% of a composite food formulated, by blending flours of millet, soybeans, rice and peanut oil. The high nutrient contents in the composite flours porridge blends in the present study, may provide a cheap and alternative source of proteins and other nutrients to the rural populations in Uganda. In the present study, the carbohydrate contents of 64.2 g/100g registered in cowpea-millet composite porridge and 88.8 g/100g registered in cowpea-maize composite are superior to the maize-wheat composites with 59.99% reported by Ajifolokun *et al.* [32]. The dietary fiber content in the two composite flour porridge blends compares well with the contents of 5.71% reported in cowpea-millet porridges in Nigeria [32] and in maize bean flour blends consumed by the Nandi communities in Kenya [33]. Adequate intake of dietary fiber is reported to have medical benefits of lowering the risk of colon cancer, constipation and many other digestive disorders and diseases [34]. The lipid contents of the two composite flours in the present study are about two fold, the content (2.67%) registered in Ugandan composite blends of maize and bean flours [35]. Based on the high fat content of the mixed flour blends, they are good sources of energy in diets.

Sensory acceptability of the cowpea porridge blends

The consumer acceptability of the porridges in the present study was much dependent on the sensory attributes such as colour, aroma, taste and mouth feel texture (Table 2). Generally, between the two composite cowpea porridges, the cowpea-millet porridge blend was significantly ($P \leq 0.05$) more appealing in terms of colour (3.61±0.8), aroma (2.96±0.2), taste (3.24±0.6) and texture (3.62±0.6) to the panellists than the cowpea-maize porridge blend. The panellists preferred the cowpea-millet because it had almost similar sensory characteristics to the plain millet porridge they are used to. The significant variations in the mean liking scores among cowpea-millet porridges and cowpea-maize porridges may be attributed to the millet flour having significantly influenced the sensory acuity and acceptability of the samples. The findings in the present study are in agreement with findings reported elsewhere in sorghum-millet porridges formulated in Nigeria [36], cassava-millet porridges formulated in Uganda [37] and complimentary porridge of millet, soybeans and grayfish powder developed in Nigeria [38].

On the contrary, scores for overall acceptability revealed that the plain millet (4.54±0.3) and maize (4.29±0.1) porridges were more significantly ($p \leq 0.05$) acceptable than composite cowpea-based millet (3.61±0.8) and composite cowpea maize (3.39±0.1) porridge. Similar trends were observed for colour, aroma, taste and texture. The higher acceptability of the plain millet and maize porridges than the cowpea-millet and cowpea-maize porridges can be attributed to the fact that the consumers were more familiar to the plain porridge blends [39] than the composite porridge blends. Bhuiyan [40] previously attributed the preference of plain millet porridge to its peculiar aroma,

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Volume 21 No. 10
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ISSN 1684 5374

colour and texture, that is appealing to children and women. Also, the low preference of composite porridges, in the present study, can be attributed to the green pigmentation of the cowpea powder, which was introduced in the blends of cowpea-millet porridge and cowpea-maize porridge, lowering the consumers' appeal to the mixed porridges. The green coloration in foods is highly correlated with the salt related foods such as soups and sauces but not the sugar related foods such as porridges [41].

Contribution of the composite porridges to the daily requirements of proteins, carbohydrates and fats of infants (6-12 months) and children (1-8 years)

The amount of foods (such as porridges) eaten habitually by children in rural settings of Africa and Uganda in particular, is estimated at around 200 g daily for infants aged 6 to 12 months and children aged 1 to 8 years [42]. Porridges are often eaten daily by children as a main meal, sometimes between main meals or while guardians perform household income activities such as farming [43]. Consequently, using these approximations for the amounts of porridge that may be consumed, the likely contributions of the two composite porridges of cowpea-millet and cowpea-maize were estimated, to meet the RDAs of proteins, carbohydrates and fats [21, 22]. The calculated potential contribution of the two porridges in the present study in reference to intakes of the proteins, carbohydrates and fats revealed that these porridges can provide substantial amounts of nutrients to both infants (6 to 12 months) and children aged 1-8 years (Table 3). For both infants and children the two composites of porridges can contribute 100% RDAs daily protein and carbohydrate requirements. The high contribution of the composite flours of cowpea-millet to RDAs for protein and carbohydrates is due to the high carbohydrate and protein concentration in both the cowpea and millet flour. The protein and carbohydrates contribution from the two composite porridges, are above the RDAs for proteins and carbohydrates. The findings revealed that the contribution of the two porridges towards proteins and carbohydrates RDAs reduced, with increase in the age of infants and children. This may be due to an increase in the body needs during growth. For example, energy is needed for maintaining body size, body composition and a desirable physical activity and to allow optimal growth and development among children, deposition of tissues, while protein is for growth and development in children [44]. Results further revealed that if an infant aged 6-12 months was fed 200g of cowpea-millet porridge or cowpea-maize porridge respectively, 38% or 30% of his or her daily fat requirements would be met. Fats are essential in the body for; calorie supply, brain development, absorption and transportation of vitamins (33-34). In order to meet the protein, fat, and energy RDAs of the older children, intake of more than 200 ml of the millet based composite porridge is recommended.

CONCLUSION

The refractance window dried cowpea leaves flour blended with millet or maize flours significantly improved the nutrient content of the composite porridges. Addition of cowpea flours in composite porridge formulations of either millet or maize, negatively affected the sensory characteristics of composite porridges. Composite cowpea-millet porridges were the most preferred with regards to their sensory characteristics, when compared with cowpea-maize porridges. Given the high protein and carbohydrate

https://doi.org/10.18697/ajfand.105.21395

content of the two porridge composites, it can be concluded that the two composite porridges can make considerable contributions towards meeting protein and carbohydrate requirements for infants (6-12 months) and children (1-8 years).

ACKNOWLEDGEMENTS

This work was supported by the Fruits and Vegetables for all Seasons (FruVaSe) project funded by the Georg – August- University of Göttingen Division Quality of Plant Crops, Department of Crop Sciences in partnership with School of Food Technology, Nutrition and Bioengineering, Makerere University.

ETHICAL REVIEW

The Ethics Committee of Makerere University concluded that cowpea and composite samples were not toxic to humans testing, in the quantities and concentrations that were served. A copy of the document approving the study was shared to reassure the panellists recruited.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Table 1: Proximate composition of the different flour blends (g/100g)* on dry weight basis

Flour blends	Protein	Carbohydrates	Dietary fiber	Lipid	Ash
Plain millet porridge	10.96^{a}±2.01	71.02^{d}±0.05	11.01^{a}±1.93	4.71^{b}±0.35	1.57^{c}±0.31
Millet porridge with CLP	13.4^{b}±0.09	64.2^{b}±0.82	12.5^{a}±0.58	5.3^{a}±0.73	3.4^{a}±09
Plain maize porridge	5.91^{c}±0.03	88.79^{c}±0.73	1.47^{b}±0.02	2.84^{d}±0.80	1.35^{c}±0.07
Maize porridge with CLP	7.6^{C} ±0.52	84.1^{a}±0.13	3.1^{c}±0.63	3.3^{c}±0.43	2.3^{b}±0.21

CLP-Cowpea leaf powder
*Values are means and standard deviation of three determinations.
Means in the same column with the same superscript letter are not significantly different determined by ANOVA test (P > 0.05)

Table 2: Sensory acceptability scores on a 5-point Likert scale for porridge made from the cowpea- based composite flours

Factor	General acceptability	Color	Aroma	Taste	Texture
Plain millet porridge	4.54^{a}±0.3	4.26^{a}±0.5	3.97^{a}±0.6	4.27^{a}±0.4	4.34^{a}±0.5
Millet porridge with CLP	3.61^{b}±0.8	3.32^{b}±0.8	2.96^{b}±0.2	3.24^{b}±0.6	3.62^{b}±0.6
Plain maize porridge	4.29^{a}±0.5	3.78^{b}±0.3	3.74^{a}±0.4	4.16^{a}±0.7	3.98^{b}±0.2
Maize porridge with CLP	3.39^{b}±0.1	2.66^{c}±0.7	2.87^{b}±0.1	3.18^{b}±0.4	3.28^{c}±0.5

CLP-Cowpea leaf powder
*Values are means and standard deviation of three determinations.
Means in the same column with the same superscript letter are not significantly different determined by ANOVA test (P > 0.05)

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Table 3: Percentage contribution of composite cowpea porridges (200g among children) to the daily requirements of proteins, carbohydrates and fats of infants (6-12 months) and children (1-8 years)

	Percentage contribution to RDAs infants and children		
Variable	Age group	Cowpea-millet porridge	Cowpea - maize porridge
Proteins [b]	0-6moths	960	660
	7-12 months	794	546
	1-3 years	672	462
	4-8 years	460	316
Carbohydrates	0-6 months	316	444
	7-12 months	199.6	280
	1-3 years	146	205
	4-8 years	144	205
Fat	0-6 months	36	30
	7-12 months	38	30
	1-3 years	ND[c]	ND
	4-8 years	ND	ND

Source: Food and Nutrition Board, (2003), Institute of Medicine, National Academies
*Adequate Intakes (AIs)
[b] Based on g protein per kg of body weight for the reference body weight, e.g., for adults 0.8 g/kg body weight for the reference body weight
[c] Not determined

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