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Proximate composition, antinutrient factors and functional properties of complementary food formulations as affected by sorghum processing methods, addition of cowpea and carrot

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Abstract
The study investigated the proximate composition, antinutrient factors and functional properties of complementary food formulated from mixtures of sorghum cultivars (pelpeli and chakalari white), cowpea and carrot. The undehulled sorghum cultivars were roasted and malted. The flours of the processed sorghum cultivars, cowpea and carrot were blended using 2x2x3x2 factorial design experiment where flours of two sorghum cultivars were processed by three methods, supplemented with cowpea and cowpea each at two levels resulting in twenty four complementary food formulations and one commercial sample. The proximate composition, functional, malting properties and antinutrient factors were evaluated using standard methods. There was significant difference ($p<0.05$) in the proximate composition of the raw materials. There was significant ($p<0.05$) difference in Protein content and energy. Higher protein was supplied (14.38%) by 70% Malted pelpeli supplemented with 30% cowpea from the formulated complementary foods. The tannin content ranged from 0.218 to 0.492 %C.E. whereas phytic acid content ranged from 1.854 to 3.862 mg/g for the sorghum cultivars. The tannin and phytic acid contents for the formulated complementary foods ranged from 0.172 to 0.492 %C.E. and 0.987 to 3.958 mg/g, respectively. There was significant ($p<0.05$) difference in bulk density. Water absorption ranged from 1.30 to 2.83 g/ml, soluble sugar ranged from 1.10 to 1.73%. There was significant ($p<0.05$) difference in pH and Titratable acidity contents in the formulated complementary foods.

Keywords: sorghum cultivars, pelpeli, chakalari, cowpea, yar'arba'in, carrot, complementary food

1. Introduction

Nigeria is a country with an abundance of food that can be used for proper nutrition, as well as for the formulation of complementary foods. Despite the abundance of foods, there is malnutrition. Malnutrition does not only persist but remains widespread in many developing countries. Protein Energy Malnutrition (PEM) and micronutrient deficiencies among infants and children have been shown to be directly and individual associated with more than 50% of all childhood morbidity and mortality in the developing world1.The WHO and UNICEF are very much concerned about this trend. This is due mainly to lack of adequate and good quality formulated complementary food formulations, poor processing methods and the presence of anti-nutritional factors such as tannin [2]. Other factors include such as cost of commercial complementary formulas, poor hygienic practices of mothers, some traditional beliefs about feeding infants with protein foods and high viscous characteristics of some commercial complementary foods are some of the constraints that predispose the infant to malnutrition and growth retardation. During the complementary feeding period, the child needs a nutritionally adequate and, calorie-dense supplementary foods in addition to the mother`s milk. This is due to the increasing nutritional demands of the growing baby [3] and the food plays a vital role in the all-round growth, development and mental health of the children. There is therefore the need to produce complementary foods that are of nutritional balanced and caloric-dense to meet the nutritional needs of the infant. It is against this background that an indigenous sorghum cultivars (pelpeli white and chakalari white) cowpea (yar'arba'in) and carrot were chosen for this research.

These indigenous sorghum cultivars are cheap and readily available and are cultivated within a short period of two months as compared to other grains like maize, rice, wheat and acha. Moreover, the sorghum cultivar (pelpeli) is believed to be medicinal by the people of babur/bura in Biu and Hawul local government areas of Borno state, Nigeria. They believed that the sorghum cultivar (pelpeli) heals forms of fracture (personal communication). However, the major constraints in the development of sorghum based foods is the level of tannins that made them to be inferior in terms digestibility and bioavailability of mineral elements [4], however, these problems can be overcome by the use of processing methods such as roasting and malting either singly or in combination to reduce the tannin content to a minimum. The use of sorghum alone in preparation of complementary foods is inadequate for the optimal nutrition of the infant, due to its quality.

The quality of protein could be improved by combination of sorghum cultivars (pelpeli white and chakalari white) and an indigenous cowpea cultivar (yar'arba'in) which is also readily available and cheap. Vitamin A deficiency is prevalent in this part of the country (Northern Eastern Nigeria), and breast milk, sorghum and cowpea are poor sources of vitamin A. Hence, the addition of 10 % carrot as indicated by Badamosi *et al*. [5] has the potential of reducing the prevalence of vitamin A deficiency among these growing infants in this part of the country as well as among developing countries where such prevalence is found.

Apart from supplementation and processes that reduces or removes antinutrient substances in complementary foods, knowing their proximate composition and functional properties are equally important. Knowledge of food composition6 and functional properties [7] of complementary food is important for nutritionist planners and understanding their behavior during preparation. Hence, the objectives of this study were to produce complementary foods from mixtures of indigenous sorghum cultivars (pelpeli white and chakalari white), cowpea (yar' arba'in) and carrot; and determine their proximate composition, antinutrient factors and functional properties.

2. Materials and Methods

The materials used for this research included indigenous sorghum cultivars (pelpeli white and chakalari white) which were purchased from Biu market in Biu Local Government area of Borno state, Nigeria, while Cowpea (Yar'arba'in) and carrot were purchased from Gamboru Vegetables Market of Jere Local Government area of Borno State, Nigeria.

2.1 Samples Preparation

The sorghum cultivars (pelpeli and chakalari) weighing 5 kg were cleaned and its percent purity was determined. The clean grain was washed, after which it was drained and roasted for 30 minutes at 180˚C. The roasted grains were milled using disc attrition mill and sieved8. Malted sorghums were prepared as described by Badau *et al*. [8]. The sorghum cultivars (pelpeli white and chakalari white) were cleaned and steeped in water (w/v) for 16 hours with one hour air rest after every 6 hours of steeping [9], after which steeped grains were spread on a clean moist Jute bag for germination. Water was sprinkled during germination occasionally to keep the grain moist. Germination was carried out for seventy two hours (72 hours) after which there were sun dried and dehusked to remove shoots. The germinative capacity, metabolic loss, malting loss and vegetative loss were determined. The malted grains were milled and sieved. Two kilograms (2 kg) of cowpea was cleaned and soaked in water at an ambient temperature (32˚C) for five minutes (5 minutes). The cowpea was dehulled using mortar and pestle, after which it was washed and dried in doom drier for 48hours. The dried grain was milled and sieved8. The carrot (5kg) was sorted, washed and diced. The diced carrot was steam blanched for two minutes and sun dried for forty eight hours (48 hours) and milled using disc attrition mill [5].

2.2 Proximate Composition

Moisture, Protein, Fat, Ash and crude fiber were determined by methods of AOAC10. Carbohydrate was calculated as described by Asma *et al*. [11] and Energy was calculated using Atwater factor as reported by Chibuzo and Ali [12].

2.3 Antinutrient Factors

Tannin content was determined by Vanillin Hydrochloric Acid quantitative method as described by Burns [13] and Phytic acid content was determined by a method based on that of Davies and Reid [14].

2.4 Functional Properties

Soluble sugars were determined by U.V Spectrophotometric method, Water absorption and capacity and Bulk Density were calculated by Adejuyitan *et al*. [15]. pH and Titratable Acidity (TA) were Determined as described by Blanco and Sherbo [16] and AOAC [17].

2.5 Formulation of the Complementary Food Blends

The complementary foods were formulated in the ratio of 70:30 as described by Marero *et al*. [18] and reported by Almeida-Dominguez *et al*. [19] and Badau *et al.* [8]. A 2×3×2×2=24 factorial design was used to formulate the complementary blends as shown in Table 1.

2.6 Statistical Analysis

The data generated was subjected to analysis of variance (ANOVA) as described by Gomez and Gomez20 and where differences exited, means were separated using Duncan Multiple Range Test [21].

3. Results and Discussion

3.1 The percentage, purity and malting properties of the sorghum cultivars.

The result of the malting characteristics of the indigenous sorghum cultivars are presented in Table 2. The percentage purity, germination capacity, metabolic loss, malting loss and vegetative loss of the sorghum cultivars ranged from 97.81 to 98.94%, 96.64 to 98.38, 0.22 to 0.24, 7.89 to 8.87 and 2.47 to 2.61, respectively.

It was reported that malting loss increases with germination period22. Cereals can be satisfactory malted but sorghums are readily available, cheap, gives least technical difficulty during matting and has been widely, used in food preparation especially for the production of African beer [23, 24]. Unlike rice, whole rice whether milled or un-milled requires auxiliary milling equipment for satisfactory malt and this is expensive and time consuming. Many attempted malting of rice during World War II and later abandon it due to difficulties in malting and because of the undesirable characteristics of the final product [25]. Adeola [22] reported malting properties of sorghum with malting properties of sorghum with a malting loss of 15.50-33.00%. It was reported that malting loss for all the sorghum cultivars reached peak between the second and third day of germination. Lager beer has been produced from 100% sorghum using exogenous enzymes as reported [26].

3.3 Proximate composition of sorghum, cowpea and carrot

The proximate composition of the indigenous sorghum cultivars, cowpea and carrot is shown in Table 3. The moisture content for the raw materials ranged from 7.70 to 11.66%. The highest moisture content was recorded in carrot flour 11.66% and the least moisture content was observed in RCW-roasted chakalari white. The unprocessed sorghum cultivars had higher ($P<0.05$) moisture content, UCW and UPW had moisture content of 10.25 and 10.16% respectively. Roasted Chakalari and roasted pelpeli had the least moisture content of 7.70 to 8.05%, respectively. This could be due roasting which decreased the moisture content. This is similar to the result reported by Magdi27. Carrot had the highest moisture content among the entire samples (11.66%). The low moisture observed for all the raw materials is a good indicator for their potential to have longer shelf life. This is in line with the findings of Vincent [28]. It is believed that materials such as flour containing more than 12% moisture have less storage stability than those with lower moisture content. For this reason, a moisture content of 10% is generally specified for flours and other related products. The protein content ranged from 3.66 to 19.83%. Cowpea flour had the highest protein content of 19.83% and carrot flour had the least 3.66%. In terms of the sorghum cultivars, there was no significant (P>0.05) difference among the unprocessed sorghum cultivars compared to the processed sorghum cultivars. However, malted Chakalari white had higher (P<0.05) protein value of 11.90%. Malting increased the protein content of the sorghum cultivars. Geleta *et al*. [29] reported similar protein content of [13] genetically diverse sorghum cultivars (7.99% to 17.8%). The result of the fat, ash and fiber showed no significant (P>0.05) difference among the sorghum cultivars. Carrot

Table 1: Formulation of the complementary food blends.

Formulation	Undehulled Chakalari (g)	Undehulled pelpeli (g)	Roasted chakalari (g)	Roasted pelpeli (g)	Malted chakalari (g)	Malted Pelpeli (g)	Cowpea (g)	Carrot (g)
UCW 001	100	00	00	00	00	00	00	00
UCW 901	90	00	00	00	00	00	00	10
UCW 703	70	00	00	00	00	00	30	00
UCW 621	63	00	00	00	00	00	27	10
UPW 001	00	100	00	00	00	00	00	00
UPW 901	00	90	00	00	00	00	00	10
UPW703	00	70	00	00	00	00	30	00
UPW 621	00	63	00	00	00	00	27	10
RCW 001	00	00	100	00	00	00	00	00
RCW 901	00	00	90	00	00	00	00	10
RCW 703	00	00	70	00	00	00	30	00
RCW 621	00	00	63	00	00	00	27	10
RPW 001	00	00	00	100	00	00	00	00
RPW 901	00	00	00	90	00	00	00	10
RPW 703	00	00	00	70	00	00	30	00
RPW 621	00	00	00	63	00	00	27	10
MCW 001	00	00	00	00	100	00	00	00
MCW 901	00	00	00	00	90	00	00	10
MCW 703	00	00	00	00	70	00	30	00
MCW 621	00	00	00	00	63	00	27	10
MPW 001	00	00	00	00	00	100	00	00
MPW 901	00	00	00	00	00	90	00	10
MPW 703	00	00	00	00	00	70	30	00
MPW 621	00	00	00	00	00	63	27	10

Table 2: Malting characteristics of the sorghum cultivars

Cultivar	Purity of grain	Germination capacity	Metabolic loss	Malting loss	Vegetative loss
Chakalari	97.81±2.62	98.38±0.10	0.24±0.16	8.97±1.52	2.61±1.02
Pelpeli	98.94±1.30	96.64±2.31	0.22±0.24	7.89±0.76	2.47±1.31

Flour had the highest ash (P<0.05) value of 11.27%. From the result obtained variations in the composition of cereal and legumes existed (Table 4) which is in line with what has been reported by other researchers and could be due to the nature of soil and type of cultivar25, 30. There was significant (P<0.05) difference in carbohydrates and energy values of the samples. Roasted chakalari white had the highest (P<0.05) carbohydrate content of 74.87% among the sorghum cultivars, while UCW sample had the least (P<0.0%) carbohydrate content (69.95%). Cowpea and carrot had carbohydrates contents of 63.53% and 68.90%, respectively. There were significant differences (P<0.05) in energy values among the samples. The energy values ranged from 306.20 to 361.91Kcal/100g. Processed sorghum cultivars had higher (P<0.05) energy values of 361.91Kcal/100g for RCW while carrot had the least energy values of 306.20Kcal/100g.

3.3 Proximate composition of complementary food formulations

The proximate composition of various complementary food formulations is presented in Table 4.The proximate composition showed that all the samples were within the normal moisture contents of dried food (flour blends). According to the results obtained, there were significant differences (P<0.05) in the moisture content of all the formulated complementary foods. The moisture content ranged from 6.27 to 10.65%. The low moisture contents were observed in samples that contained roasted chakalari and pelpeli sorghum cultivars. The samples that contained roasted raw materials and had low moisture contents were RCW 001(7.70%), RCW 90(8.06%), RCW 703 (8.39%), RPW 001 (8.05%), RPW 901 (8.06%) and RPW 621 (8.35%). The low moisture contents observed in the roasted samples could be due to the roasting process which might have removed some quantity of water due to the dry heat. Complementary foods that contained malted sorghum had moisture contents ranging from 10.65% (MPW) to 10.10% (MPW 703). It is also very close to that of Amankwah *et al*. [4] which ranged from 5-6% who formulated foods from fermented maize, rice, soybean and fishmeal. However, the result is slightly greater than the recommended moisture content (<5%) by Codex31 and Asma *et al*. [11]. The low moisture content obtained from these results is a good indicator of their potential to have longer shelf life. This is in line with findings of Vincent28. It is believed that materials such as flour and starch containing more than 12% moisture have less storage stability than those with lower moisture content. The protein content ranged between 7.5 – 14.38% as shown in Table 4. The protein content for all the formulated complementary foods was significantly different (P<0.05) from each other. The values obtained compared well with the RDA value of 13g/day. MPW 703 had the highest protect value (14.38%) among the formulated foods. Protein is needed for tissue replacement, deposition of lean body mass, and growth and because of rapid growth in infancy protein requirements are to be high per kilogram of weigh than that of older children [32]. The high protein content of the formulations could be due to addition of cowpea.

Table 3: Proximate Compositions of the Raw Materials

	Moisture(%)	protein (%)	fat (%)	ash (%)	fiber(%)	CHO(%)	Energy(Kcal)
UCW	10.25±0.05bc	11.90±0.11b	3.17±0.45a	2.27±0.25cd	2.47±0.35ab	69.95±0.57c	355.90±1.65bc
UPW	10.16±0.50bc	11.08±0.18cd	2.40±0.36bc	2.53±0.15c	2.20±0.35ab	71.63±1.11b	352.44±1.82bc
RCW	7.70±0.56e	10.45±0.30e	2.30±0.30bc	2.53±0.25c	2.10±0.17b	74.87±0.26a	361.91±2.80a
RPW	8.05±0.01e	10.69±0.19de	2.80±0.40ab	2.50±0.10c	2.33±0.21ab	73.62±0.71a	361.43±0.30a
MCW	9.37±0.60cd	11.46±0.04c	2.43±0.51bc	2.17±0.12cd	2.27±0.25ab	72.24±0.43b	356.74±3.30ab
MPW	10.65±1.03b	10.40±0.52e	2.37±0.15bc	2.10±0.17d	2.43±0.45ab	71.85±1.28b	350.30±5.55c
CFS	8.51±0.03de	19.83±0.11a	2.07±0.15c	3.96±0.15b	2.10±0.10b	63.53±0.27d	352.05±1.34bc
CRF	11.66±0.15a	3.66±0.19f	1.77±0.31c	11.27±0.31a	2.73±0.31a	68.90±0.56c	306.20±4.05d

Means within each column not followed by the same superscripts are significantly different (P<0.05)
UCW: Underhulled Chakalari; UPW: Undehulled Pelpeli; RCW: Roasted Chakalari white; RPW: Roasted Pelpeli white; MCW: Malted Chakalari white; MPW: Malted pelpeli white; CFS: Cowpea flour; CRT: Carrot flour

The result was similar with Saeeda *et al*. [33], who reported 14.5% crude protein of complementary food from maize, lentil, carrot and sesame blend but is less than that of Ijarotimi and Keshinro34 whose complementary food crude protein of 23.85 to 28.84% formulated from germinated and fermented popcorn but higher than that of Bojnanska *et al*. [35] (12.57%). The difference could be due to the difference in blending ration, crop type and the processing methods used during the formulations.

The required daily allowance for protein contents in the complementary foods is less than 15%36. Diets of infants should be supplemented with additional sources of high quality protein such as cereal/legume blends. The best formulation from the analysis was MPW 703 (14.38%). The fat content ranged between 2.33 to 3.17%. The highest fat content was recorded by UCW 001 blend and the least was MCW 901 blend. The result showed that processing methods used on the samples did not affect the fat content. Neither roasting nor malting methods did increase the fat content as shown in Table 4. The result is different with that of Ghavidel and Davoodi28 who reported 1.3% crude fat in complementary food processed from wheat and green gram, and 1.27% crude fat from wheat and lentil seed flour composites. However, the result is lower than that of Solomon37 (11.5 to 24.8%) who processed complementary foods from rice, maize, acha, soybean, bambaranut, benniseed, carrot, garden egg and crayfish. The result is less than the daily recommended fat content in complementary foods range from 10-25%36. This may be due to the difference in crop types used, ration and the processing methods employed during the formulation of the complementary foods. However, fat content was higher in the control than in the formulated complementary foods. Fats play a vital role in infant nutrition, apart from its provision of fatty acids essential for growth, as source of energy and fat soluble vitamins. The total ash content in the formulated complementary foods ranged from 2.03 to 2.80%. The highest ash content was recorded by MCW 901 that is malted chakalari 90% and carrot 10% and the least ash content was recorded in MPW 621, that is malted pelpeli 63%, cowpea 27% and carrot 10%. Similar results were reported by Bojnanska *et al*. [35] and Gibson and Hotz [38] when legumes (lentil and chickpea) are included into cereal based complementary foods. All the formulated complementary foods processed in this research did not meet the recommended ash content by WHO/FAO35 in the complementary food (<5g/100g). This could be due to the processing methods and types of crop used in formulating the complementary foods. Crude fiber content for the study is shown in Table 4. The crude fiber content ranged from 2.03±0.06% to 2.80±0.10%. The highest crude fiber content was recorded in sample MCW 901(2.83±0.40%) and the least crude fiber content was recorded in sample MCW 621 (2.03±0.06%). This results did not meet the recommended allowance for fiber in the complementary food of <50%. The carbohydrate contents in the formulated complementary foods ranged between 68.42 and 74.87%. There varied significantly (P<0.05). The highest carbohydrate content was recorded in sample RCW 001 higher carbohydrate contents were observed in samples that were not supplemented with cowpea and carrot. This was in agreement with the findings of Jimoh and Olatidoye [39] who reported a decrease in carbohydrate content with increase in soybean flour fortification. The carbohydrate contents of the formulated complementary contents of the formulated complementary foods was higher than the carbohydrate content of the control (Cerelac) but less than the recommended daily allowance of 130g/d. Similar results were reported by Elemo *et al*. [40] and Hussain *et al*. [41] who reported 63.7% - 77.4% of carbohydrate content in complementary food processed from sorghum and cowpea, and 61.24-70.73% from wheat and lentil composite flour, respectively. All the formulated complementary foods processed meet the carbohydrate content recommended by WHO/FAO42 in the complementary food (>65g/100g). The energy levels of the formulated complementary foods are shown in table 4. Energy was recorded to be high for all the formulations. Higher energy values were obtained in the formulations than in the control, higher energy values were also obtained in formulations that were supplemented with cowpea and the result is in consistent with those obtained by Mbayi *et al*. [43]. Processed formulations that were supplemented with cowpea had higher energy values that unprocessed and unsupplemented formulations. The highest energy value was obtained in formula RCW 621 (362.48±1.41Kcal) and the least was observed in formula MCW 901 (348.27±4.66Kcal). Similar result (376.23-376.27Kcal/100g) was also reported by Hussain *et al*. [41] who formulated complementary food from wheat and lentil composite flour. However, the result is less than the recommended energy contents by WHO/FAO35 in the complementary foods (400-425kcal/100g). This may be due to the less fat content of the raw materials used in the formulation of the foods. Energy content is a parameter used to determine the quality of food especially for formulations designed for adult with high energy requirements.

Table 4: Proximate composition of formulated complementary foods as affected by sorghum processing methods, addition of cowpea and carrot

Formulations	Moisture(%)	protein(%)	fat(%)	Ash(%)	Fibre(%)	CHO(%)	Energy(Kcal)
UCW001	10.25±0.05^{abc}	11.90±0.11^{fg}	3.17±0.45^{a}	2.27±0.25^{bcd}	2.47±0.35^{ab}	69.95±0.57^{ghi}	355.90±1.65^{cdef}
UCW901	9.60±0.20^{def}	9.87±0.06^{l}	2.23±0.25^{c}	2.43±0.15^{abcd}	2.27±0.25^{b}	73.59±0.51ab	353.97±0.84^{efg}
UCW703	10.35±0.15^{ab}	13.50±0.99^{cd}	2.97±0.25^{ab}	2.17±0.15^{cd}	2.53±0.25^{ab}	68.49±0.83^{jk}	354.63±1.25^{defg}
UCW621	9.86±0.26^{bcdef}	10.63±0.54^{jk}	2.77±0.21^{abc}	2.30±0.26^{bcd}	2.23±0.21^{b}	72.54±0.88^{bcd}	356.38±1.47^{cdef}
UPW001	10.16±0.50abcd	11.08±0.18hij	2.47±0.06^{bc}	2.53±0.15^{abc}	2.20±0.35^{b}	71.63±1.11^{def}	352.44±1.82^{fgh}
UPW901	9.97±0.06^{bcde}	11.20±0.13^{hij}	2.67±0.31^{abc}	2.10±0.17^{cd}	2.23±0.15^{b}	71.82±0.21^{def}	356.11±2.62^{cdef}
UPW703	8.75±0.19^{gh}	13.35±0.50^{cde}	2.57±0.21^{abc}	2.40±0.40^{abcd}	2.33±0.29^{ab}	70.82±0.99^{efgh}	360.65±1.86^{abc}
UPW621	9.85±0.05^{bcdef}	12.97±0.17^{dc}	2.83±0.12^{abc}	2.33±0.25^{abcd}	2.40±0.36^{ab}	69.82±0.74^{ghij}	356.15±2.12^{cdef}
RCW001	7.70±0.56^{j}	10.43±0.29^{kl}	2.30±0.30^{c}	2.53±0.25^{abc}	2.10±0.17^{b}	74.87±0.26^{a}	361.91±2.80^{ab}
RCW901	8.06±0.01^{ij}	11.99±0.07^{f}	2.83±0.15^{abc}	2.47±0.15^{abcd}	2.43±0.15^{ab}	72.25±0.08^{bcde}	362.42±1.23^{a}
RCW703	8.39±0.54^{hi}	12.99±0.04^{de}	2.53±0.45^{bc}	2.70±0.20^{ab}	2.43±0.25^{ab}	70.95±1.38^{efgh}	360.13±5.13^{abcd}
RCW621	8.06±0.03^{ij}	13.58±0.18^{cd}	2.53±0.12^{bc}	2.27±0.25^{bcd}	2.37±0.31^{ab}	71.19±0.52^{defg}	362.48±1.41^{a}
RPW001	8.05±0.01^{ij}	10.69±0.19^{ijk}	2.80±0.40^{abc}	2.50±0.10^{abcd}	2.33±0.21^{ab}	73.62±0.71^{ab}	362.43±1.53^{a}
RPW901	8.06±0.02^{ij}	11.32±0.62^{ghi}	2.47±0.50^{bc}	2.37±0.35^{abcd}	2.33±0.15^{ab}	73.40±1.12^{bc}	361.08±2.93^{abc}
RPW703	8.62±0.10^{hi}	12.80±0.18^{e}	2.60±0.52^{abc}	2.73±0.15^{ab}	2.27±0.15^{b}	71.00±0.60^{efgh}	358.59±2.39^{abcde}
RPW621	8.35±0.17^{hi}	13.44±0.45^{cde}	2.40±0.26^{bc}	2.43±0.06^{abcd}	2.20±0.35^{b}	71.18±0.86^{defg}	360.08±2.66^{abcd}
MCW001	9.37±0.60^{ef}	11.46±0.04^{fgh}	2.43±0.51^{bc}	2.17±0.12^{cd}	2.33±0.29^{ab}	72.24±0.43^{bcde}	356.74±3.30^{bcdef}
MCW901	9.66±0.06^{cdef}	10.79±0.31^{ijk}	2.33±0.15^{c}	2.80±0.10^{a}	2.83±0.40^{a}	71.25±0.85^{defg}	348.27±4.66^{h}
MCW703	9.65±0.05^{cdef}	13.75±0.26^{bc}	2.50±0.50^{bc}	2.47±0.42^{abcd}	2.43±0.06^{ab}	69.20±0.23^{ijk}	354.30±4.40^{efg}
MCW621	9.32±0.07^{f}	13.15±0.15^{cde}	2.60±0.26^{abc}	2.30±0.30^{bcd}	2.03±0.06^{b}	70.59±0.50^{fgh}	358.37±1.65^{abcde}
MPW001	10.65±1.03^{a}	10.40±0.52^{kl}	2.37±0.15^{bc}	2.10±0.17^{cd}	2.43±0.45^{ab}	71.85±1.28^{def}	350.30±5.55^{gh}
MPW901	9.65±0.06^{cdef}	11.26±0.12^{hij}	2.67±0.23^{abc}	2.50±0.44^{abcd}	2.37±0.23^{ab}	72.10±0.50^{cde}	357.45±2.21^{abcdef}
MPW703	10.10±0.10^{abcd}	14.38±0.31^{a}	2.63±0.25^{abc}	2.20±0.26^{cd}	2.27±0.25^{b}	68.42±0.65^{k}	354.89±2.50^{defg}
MPW621	9.28±0.24^{fg}	14.24±0.14^{ab}	2.53±0.06^{bc}	2.03±0.15^{d}	2.30±0.20^{b}	69.61±0.65^{hijk}	358.20±2.43^{abcde}

Means within each column not followed by the same superscript are significantly different (P<0.05)

UDW 001-100% ungehulled chakalari white; UDW 901-90% undehulled chakalari white and 10% carrot flour; UDW 703-70% undehulled chakalari white and 30% cowpea flour; UDW 621-63% undehulled chakalari, 27% cowpea and 10% carrot; UPW 001-100% undehulled pelpeli white; UPW 901-90% undehulled pelpeli and 10% carrot; UPW 703- 70% undehulled pelpeli and 30% cowpea; UPW 621-63% undehulled pelpeli, 27% cowpea and 10% carrot; MCW 001-100% malted chakalari white; MCW 901-90% malted chakalari and 10% carrot; MCW 703-70% malted chakalari and 30% cowpea; MCW 621-63% malted chakalari, 27% malted chakalari and10% carrot; MPW 001-100% malted pelpeli white; MPW 901-90% malted pelpeli and 10% carrot; MPW 703-70% malted pelpeli and 30% cowpea; MPW 621-63% malted, 27% cowpea and 10% carrot; RCW 001-100% roasted chakalari white; RCW 901-90% roasted chakalari and 10% carrot; RCW 703-70% roasted chakalari and 30% cowpea; RCW 621- 63% roasted chakalari, 27% cowpea and 10% carrot; RPW 001-100% roasted pelpeli white; RPW 901-90% roasted pelpeli and 30% cowpea; RPW 703-70% roasted pelpeli and 30% cowpea; RPW 621-63% roasted pelpeli, 27% cowpea and 10% carrot.

3.4 Antinutrient factors of sorghum cultivars

3.4.1 Tannin content of sorghum cultivars

The results of the Tannin content of the sorghum cultivars is shown in Table 5.The tannin content ranged from 0.218 to 0.492 % C.E. (Percent catechin equivalent). The tannin content of the unprocessed sorghum cultivars was found to be higher in values, than the processed samples. There was more reduction in the tannin content of processed 0.218 %C.E. RPW 0.337 %C.E. than the unprocessed UCW 0.480 %C.E. and UPW 0.492 %C.E. The results of the tannin contents are within the range of the values reported by Mate *et al*. [44]. Roasting reduced the levels of tannin contents with up to 59.41%. This could be attributed to the rate of heat transfer during roasting and the sorghum as whole. It has been reported that pigmented sorghum cultivars contains more tannins as studied by Uche *et al*. [45].

The tannin content of the complementary food formulations significantly (P<0.05) varies among the formulated complementary foods. The tannin contents ranged from 0.172 %C.E. (RPW 621) to 0.492 %C.E. (UPW 001). Tannin contents were higher in complementary food formulations that contained unprocessed sorghum cultivars and processed samples had the least values. However, complementary food formulations with roasted sorghum cultivars supplemented with cowpea and carrot, RCW 001, RCW 901, RCW 703, RCW 621, RPW 001. RPW 901, RPW 703, RPW 621 had the least tannin contents compared to samples with malted sorghum cultivars MCW 001, MCW 901, MCW 703 and MCW 621. Roasting and malting significantly (P<0.05) reduced the levels of tannin contents. This could be attributed to the rate of heat transfer during roasting. It has been reported that pigmented sorghum cultivars contains more tannins as studied by Uche *et al*. [45]. Reduction in the antinutritional factors was due to heat labile of most ant nutritional factors in foods as reported by Leiner [46]. Tannins are highly reactive and unstable compounds that can be physically, chemically and biologically degraded [47, 48]. This is true for Chakalari white and Chakalari red. Reduction in tannin content due to processing might have been caused by the activity of polyphenol oxidase on tannins which hydrolysis tannic acids into inositol and orthophosphate [49].

3.4.2 Phytic acid content of sorghum cultivars

The phytate content of the sorghum cultivars ranged from 1.854 mg/g to 3.862 mg/g (Table 5). The result obtained showed that higher values of phytate content were observed in the unprocessed sorghum cultivars UPW (3.862 mg/g) and UCW (3.756 mg/g). Lower values of phytate content were observed in the processed sorghum cultivars MCW (2.808 mg/g) and MPW (3.351mg/g), because most cereal and legumes contain high levels of phytic acid50. Decortication and milling remove most of the phytate as earlier reported by Henry and AhistrOm50. Roasting significantly (P<0.05) reduced the levels of phytate contents as the values reported by mate *et al*. [44]. Reduction in antinutritional factors implies increase in bioavailability of minerals and protein51. It is the storage form of phosphorus in cereals and is usually located in the outer layer of cereals and legumes [50]. Generally, cereal has been regarded as the major sources of dietary phytate [49]. Steeping and germination decreased the phytic acid content of pearl millet cultivars. Gupta and Sehgal [52] have observed decreased in phytic acid contents of cereal grains used for preparing complementary foods as a result of soaking and germination. The decrease in the level of phytic acid during soaking may be attributed to leaching out into soaking water under the concentration gradient. Other researchers have reported, decrease in the level of phytic acid during soaking [53, 54] and germination. But recent findings have shown it has some beneficial effects. Recent information showed that phytates possess potential ability to lower blood glucose, reduce cholesterol risks triacylycerols, and reduces the risk of cancer and heart disease [55, 56]. Phytic acid content also decreased significantly (P<0.05) with increase in germination time61. Phytic acid is also released when the grain germinates [57, 50].

Table 5: Tannin and phytate contents of the sorghum cultivars

Samples	Tannin C.E. (%)	Phytate(mg/g)
UCW	0.480±0.002^{b}	3.756±0.004^{b}
UPW	0.492±0.001^{a}	3.862±0.002^{a}
RCW	0.218±0.002^{f}	1.854±0.002^{f}
RPW	0.337±0.002^{e}	2.183±0.002^{e}
MCW	0.418±0.002^{c}	2.808±0.002^{d}
MPW	0.413±0.002^{d}	3.351±0.002^{c}

UCW: Underhulled Chakalari; UPW: Undehulled Pelpeli; RCW: Roasted Chakalari white; RPW: Roasted Pelpeli white; MCM: Malted Chakalari white; MPW: Malted pelpeli white; CFS: Cowpea flour; CRT: Carrot flour; C. E.: Catechin Equivalent

3.5 Functional properties of complementary food formulations

The result of the functional properties of the complementary foods is shown in Table 6: Result of the investigation showed significant (p<0.05) differences in the complementary food formulations functional properties existed. The unprocessed indigenous sorghum cultivars (chakalari and pelpeli) flours had higher bulk density of 0.77g/ml compared with malted sorghum flours from the two indigenous cultivars which had the least bulk density of 0.71g/ml. The use of malted sorghum reduces dietary bulk, because malting produces and activates amylolytic and proteolytic enzymes which rapidly breakdown starch and protein into more soluble products. As the starch is broken down by the amylolytic enzymes, its water binding capacity is reduced, releasing the water trapped in the gel sturdier and producing a more Bulk density is an important factor. It measures weight per unit volume of food. High bulk density of food is required for easy packaging, transportation and energy density (allows more weight of food per limited). Nutritionally, loose bulk density promotes easy digestibility of food products, especially among children with immature digestive systems. The significance of this is that less bulky flours will have higher nutrient density since more flour can be packed in a given volume. The water absorption capacity ranged from 1.30 g/ml (undehulled chakalari) to 2.83 g/ml (703 roasted pelpeli white). There exist a significant difference (P<0.05) among samples. However, complementary food formulations that were roasted had higher (2.83 g/ml) water absorption capacities than malted. There was also minimal variability in water absorption capacity among the complementary food formulations. Water absorption capacity is an important processing parameter and has implications for viscosity. It is also important in bulking and consistency of products, as well as in baking application58. Water absorption capacity is the ability of a product to dissociate with water under a condition where water is limiting. The significance of a lower water absorption capacity of the complementary food formulations is that it will have a lower water absorption and binding capacity which is desirable for making thinner, gruels with high, caloric density per unit volume. This is in agreement with the findings of Elkahalifa *et al*. [59] on functional properties of fermented sorghum flour. However, high protein contents can also result in higher values for water absorption capacity, because proteins are hydrophilic in nature and

Table 6: Functional properties of the formulated complementary foods as affected by sorghum processing methods, addition of cowpea and carrot

Formulations	Bulk Density	Water absorption	Soluble sugar	pH	TA
UCW001	0.77±0.02^{a}	1.30±0.10^{h}	1.50±0.10^{abc}	6.30±0.10^{bcd}	0.70±0.10^{def}
UCW901	0.75±0.02^{bcd}	2.50±0.10^{abc}	1.50±0.10^{abc}	6.20±0.10^{cde}	0.70±0.10^{def}
UCW703	0.71±0.01^{e}	2.20±0.20^{cde}	1.20±0.20^{cd}	6.20±0.10^{cde}	1.10±0.10^{abc}
UCW621	0.73±0.01^{cde}	2.10±0.10^{cdef}	1.40±0.10^{abcd}	6.10±0.10^{de}	1.13±0.12^{abc}
UPW001	0.73±0.02^{cde}	1.60±0.10^{fgh}	1.67±0.31^{ab}	6.13±0.06^{de}	0.80±0.20^{cdef}
UPW901	0.73±0.01^{cde}	1.50±0.30^{gh}	1.50±0.10^{abc}	6.20±0.10^{cde}	1.03±0.15^{abcd}
UPW703	0.73±0.01^{cde}	1.53±0.42^{gh}	1.67±0.31^{ab}	6.33±0.15^{bcd}	1.17±0.47^{abc}
UPW621	0.74±0.01^{bcd}	1.93±0.31^{defg}	1.10±0.10^{d}	6.40±0.10^{abc}	1.37±0.21^{a}
RCW001	0.73±0.01^{cde}	2.30±0.10^{bcd}	1.40±0.10^{abcd}	6.10±0.10^{de}	0.67±0.15^{def}
RCW901	0.72±0.02^{de}	2.97±0.59^{a}	1.33±0.21b^{cd}	6.60±0.10^{a}	1.17±0.35^{abc}
RCW703	0.71±0.01^{e}	2.20±0.20^{cde}	1.67±0.15^{ab}	6.40±0.10^{abc}	1.17±0.35^{abc}
RCW621	0.74±0.02^{bcd}	2.63±0.35^{abc}	1.17±0.15^{cd}	6.30±0.10^{bcd}	1.10±0.10^{abc}
RPW001	0.71±0.01^{e}	2.10±0.10^{cdef}	1.20±0.20^{cd}	6.40±0.10^{abc}	0.63±0.15^{ef}
RPW901	0.73±0.01^{cde}	2.53±0.42^{abc}	1.10±0.10^{d}	6.33±0.15^{bcd}	0.80±0.10^{cdef}
RPW703	0.74±0.02^{bcd}	2.83±0.35^{ab}	1.33±0.15^{bcd}	6.50±0.10^{ab}	1.10±0.10^{abc}
RPW621	0.75±0.01^{ab}	2.63±0.40^{abc}	1.10±0.10^{d}	6.10±0.10^{de}	1.30±0.10^{ab}
MCW001	0.74±0.02^{bcd}	1.60±0.20^{fgh}	1.10±0.10^{d}	6.10±0.10^{de}	0.50±0.10^{f}
MCW901	0.75±0.01^{ab}	2.63±0.35^{abc}	1.73±0.31^{a}	6.10±0.10^{de}	0.50±0.10^{f}
MCW703	0.75±0.01^{ab}	1.40±0.20^{gh}	1.73±0.31^{a}	6.20±0.10^{cde}	1.40±0.20^{a}
MCW621	0.76±0.02^{ab}	1.60±0.20^{fgh}	1.10±0.10^{d}	5.80±0.10^{gh}	1.30±0.10^{ab}
MPW001	0.76±0.01^{ab}	2.37±0.21^{bcd}	1.30±0.10^{d}	5.73±0.31^{gh}	0.60±0.20^{ef}
MPW901	0.73±0.01^{cde}	2.43±0.49^{abcd}	1.10±0.10^{cd}	5.60±0.10^{h}	0.60±0.20^{ef}
MPW703	0.71±0.01^{e}	1.50±0.10^{gh}	1.33±0.15^{bcd}	5.83±0.21^{fg}	0.97±0.35^{bcde}
MPW621	0.75±0.01^{ab}	1.70±0.10^{efgh}	1.17±0.15^{cd}	6.03±0.06^{ef}	0.70±0.10^{def}

Means within each column not followed by the same superscripts are significantly different (P<0.05)

UDW 001-100% ungehulled chakalari white; UDW 901-90% undehulled chakalari white and 10% carrot flour; UDW 703-70% undehulled chakalari white and 30% cowpea flour; UDW 621-63% undehulled chakalari, 27% cowpea and 10% carrot; UPW 001-100% undehulled pelpeli white; UPW 901-90% undehulled pelpeli and 10% carrot; UPW 703- 70% undehulled pelpeli and 30% cowpea; UPW 621-63% undehulled pelpeli, 27% cowpea and 10% carrot; MCW 001-100% malted chakalari white; MCW 901-90% malted chakalari and 10% carrot; MCW 703-70% malted chakalari and 30% cowpea; MCW 621-63% malted chakalari, 27% malted chakalari and10% carrot; MPW 001-100% malted pelpeli white; MPW 901-90% malted pelpeli and 10% carrot; MPW 703-70% malted pelpeli and 30% cowpea; MPW 621-63% malted, 27% cowpea and 10% carrot; RCW 001-100% roasted chakalari white; RCW 901-90% roasted chakalari and 10% carrot; RCW 703-70% roasted chakalari and 30% cowpea; RCW 621- 63% roasted chakalari, 27% cowpea and 10% carrot; RPW 001-100% roasted pelpeli white; RPW 901-90% roasted pelpeli and 30% cowpea; RPW 703-70% roasted pelpeli and 30% cowpea; RPW 621-63% roasted pelpeli, 27% cowpea and 10% carrot

Table 7: Tannin and phytate contents of the complementary food formulations as affected by sorghum processing methods addition of cowpea and carrot

Samples	Tannin g/100g	Phytate mg/g
UCW001	0.480±0.002^{b}	3.756±0.004^{c}
UCW901	0.302±0.001^{m}	2.677±0.002^{i}
UCW703	0.389±0.002^{g}	3.713±0.002^{d}
UCW621	0.232±0.002^{q}	1.831±0.002^{t}
UPW001	0.492±0.001^{a}	3.862±0.002^{b}
UPW901	0.305±0.001^{l}	2.435±0.002^{l}
UPW703	0.348±0.002^{j}	3.023±0.002^{g}
UPW621	0.277±0.002^{o}	2.075±0.002^{p}
RCW001	0.218±0.002^{r}	1.854±0.002^{s}
RCW901	0.176±0.002^{u}	0.987±0.001^{x}
RCW703	0.242±0.001^{p}	1.902±0.001^{r}
RCW621	0.192±0.002t	1.367±0.002^{v}
RPW001	0.337±0.002^{k}	2.183±0.002^{n}
RPW901	0.204±0.002^{s}	1.483±0.002^{u}
RPW703	0.354±0.002^{l}	2.353±0.002^{m}
RPW621	0.172±0.001^{v}	1.344±0.002^{w}

MCW001	0.418±0.002[e]	2.808±0.002[h]
MCW901	0.291±0.002[n]	1.927±0.001[q]
MCW703	0.454±0.002[c]	3.688±0.002[e]
MCW621	0.373±0.001[h]	2.157±0.001[o]
MPW001	0.413±0.002[f]	3.353±0.003[f]
MPW901	0.356±0.002[i]	2.666±0.003[j]
MPW703	0.425±0.001[d]	3.958±0.001[a]
MPW621	0.307±0.002[l]	2.527±0.002[k]
Control	0.000±0.000[w]	0.200±0.000[x]

Means within each column not followed by the same superscripts are significantly different (P<0.05)

UDW 001-100% undehulled chakalari white; UDW 901-90% undehulled chakalari white and 10% carrot flour; UDW 703-70% undehulled chakalari white and 30% cowpea flour; UDW 621-63% undehulled chakalari, 27% cowpea and 10% carrot; UPW 001-100% undehulled pelpeli white; UPW 901-90% undehulled pelpeli and 10% carrot; UPW 703- 70% undehulled pelpeli and 30% cowpea; UPW 621-63% undehulled pelpeli, 27% cowpea and 10% carrot; MCW 001-100% malted chakalari white; MCW 901-90% malted chakalari and 10% carrot; MCW 703-70% malted chakalari and 30% cowpea; MCW 621-63% malted chakalari, 27% malted chakalari and10% carrot; MPW 001-100% malted pelpeli white; MPW 901-90% malted pelpeli and 10% carrot; MPW 703-70% malted pelpeli and 30% cowpea; MPW 621-63% malted, 27% cowpea and 10% carrot; RCW 001-100% roasted chakalari white; RCW 901-90% roasted chakalari and 10% carrot; RCW 703-70% roasted chakalari and 30% cowpea; RCW 621- 63% roasted chakalari, 27% cowpea and 10% carrot; RPW 001-100% roasted pelpeli white; RPW 901-90% roasted pelpeli and 30% cowpea; RPW 703-70% roasted pelpeli and 30% cowpea; RPW 621-63% roasted pelpeli, 27% cowpea and 10% carrot

Will make the complementary food to absorb and bind more water. There was no significant (P<0.05) difference soluble sugar among the complementary food formulations. However, unprocessed complementary foods had higher soluble sugar values while samples that contained malted sorghum cultivars had the least solution sugar values. The pH of the complementary food formulations ranged from 5.60 to 6.60, titrable acidity 0.50 to 1.30.The result of pH and titrable acidity indicated that pH decreases and titrable acidity increases in complementary food formulations that contained malt. This result is consistent with earlier report [4, 11, 60] where a similar research was carried out. Complementary food formulations MCW621, MPW001, MPW901 and MPW 703 and MPW 621 had lower pH values of 5.60 to 5.83. Undehulled and roasted complementary foods did not show any significant values. pH is an important functional property and an index of food preservation. The values of pH obtained were within the acceptable level (5.5-6.5). It is a good indication of the possibility of microbial proliferation [61, 62].

4. Conclusion

The results obtained showed that malting and roasting had reduced the anti nutrient factors of the indigenous sorghum cultivars. Addition of cowpea and carrot improved the nutrient content of the complementary food blends especially vitamin A as it has the potential of reducing the prevalence of vitamin A deficiency among growing infants.

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