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Chemical, Anti-Nutritional Factors and Sensory Properties of Maize-Kidney Bean Flours

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Abstract

In recent years, research efforts in developing countries have focused on the improvement of protein quality of food products due to mass malnutrition. TUWO is a traditional food made from maize flour and consumed by all ages in Nigeria. Flours blends were obtained from Maize and kidney bean flours using the following proportions: A= (100% maize flour as control), B= (90:10), C= (85:15), D= (80:20), E= (75:25). Products were analysed for proximate, functional, pasting, antinutrients and sensory properties. Proximate analysis showed increased in moisture, protein, ash, fiber contents while the reverse was the case for carbohydrate and fats. Functional analysis revealed bulk, water absorption and swelling capacities decreased while foaming, gelatinization, oil absorption capacities increased as substitution of kidney bean flour increased indicating good attributes suitable for food production. Pasting analysis showed increased in peak, trough, final, setback, and peak temperature as the kidney bean flour increased while the reverse was the case for peak time and breakdown viscosities. The antinutrients factors (Phytate, Tannins, Oxalate and Trypsin inhibitor) were found to be within the acceptable levels. The result of the sensory scores showed that sample C was the most liked among the entire samples at the ratio of (85% maize flour and 15 % kidney beans flours). Kidney beans and maize flour can be used to improve the nutrient composition and other quality attribute of TUWO.

Keywords: Maize Flour; Kidney Beans Flour; TUWO

Introduction

Maize a cereal grain, also known as corm has become a staple food in many parts of the world, with total production surpassing that of wheat or rice. However, not all of this maize is consumed directly by humans. Some of the maize production is used for corn ethanol, animal feed and other maize products, such as corn starch and corn syrup. The six major types of corn are dent corn, flint corn, pod corn, popcorn, flour corn, and sweet corn [1].

Maize TUWO is one of the food products that can be obtained from Maize in Nigeria. It is essentially a food gel or dumpling which is stiff, has a yield value and can be moulded into shapes [2]. However, the utilization of TUWO and maize generally is limited by its extremely low protein content and so the consumption of its products has been implicated in malnutrition. Kidney bean is popular additions to various cuisines due to their high protein content and delicacy, along with the presence of some antioxidants, minerals and polyphenols. Kidney bean is rich in protein; one cup of boiled kidney bean (177g) contains approximately 15g of protein, accounting for 27% of the total caloric content.

Starch is predominantly made up of long chains of glucose, called amylose and amylopectin. Bean have a relatively high proportion of amylose (30-40%) compared to most other dietary sources of starch. Amylose is not as digestible as amylopectin [3]. For this reason, bean starch is a slow-release carbohydrate, its digestion takes longer and it causes lower and more gradual rise in blood sugar than other types of starch, making kidney bean particularly beneficial for people with diabetes. Resistant starch has been defined as the fraction of starch, which escapes digestion in the large intestine [4]. Resistant starch offers an exciting new potential.

The study therefore aimed at evaluating the chemical, Anti-nutritional Factors and Sensory Properties of Maize-Kidney bean flours.

Materials and Methods

Kidney beans and maize samples were collected randomly from the market in Plateau state during the period under review and the flour were prepared for the various analyses. Measuring Scale, Bowls, spoons, weighing balance, Soxhet apparatus, muffle cobalite, ground glass stopper retort stand and Pots were obtained from the Veterinary Biochemistry Department, Federal University of Jos, Plateau State.

Preparation of Maize and Kidney Bean Flour

The method of Bolade MK, et al. [5] was used to prepare the both flours as shown in Figure 1. Picking out stones and some debris, was followed by grinding to homogenization using pestle and mortar and was passed through 250mm sieve clothe to obtain the flour. Flour samples for chemical analysis were kept in air tight plastic bottles and frozen at - 260c in a laboratory freezer ready for the trials. Flow chart for composite TUWO production is showed in Figure 2 & Table 1.

Preparation of Maize flour

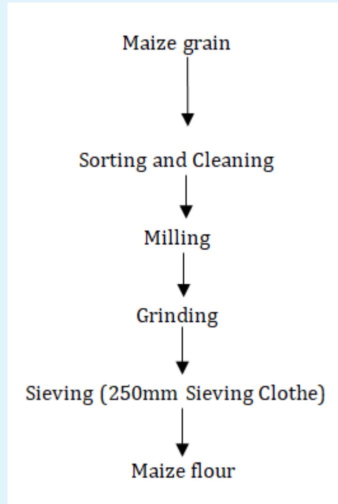

Figure 1: Flow chart for the production of maize flour.
Source: [5]

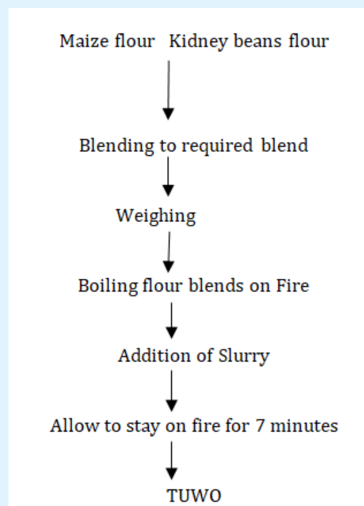

Figure 2: Flow chart for composite TUWO production.
Source: [5] with modification.

SAMPLES	MAIZE FLOUR (MF)	(KBF)	TOTAL
A	100	-	100
B	90	10	100
C	85	15	100
D	80	20	100
E	75	25	100

Table 1: Flour Blends Formulation.
Blend formulation for maize and kidney beans composite flours is presented in table 1.

Production of TUWO

Maize "TUWO" was prepared using the method described by Bolade MK, et al. [5]. In the first step, cold slurry of the flour was first prepared by mixing 20% of the desired quality of flour (40g) with 25% of the desired quantity of water (1.5l). This was followed by bringing 60% of the water into boiling and the initially prepared cold slurry was added to boiling water coupled with vigorous stirring, using a wooden flat spoon, to form a pap-like consistency. The remaining quantity of the flour (80%) was added gradually to the boiling pap-like paste with continuous stirring, and allowed to cook for about 7 min after which it was stirred vigorously to ensure smoothness of the gel. The final product obtained was called maize "TUWO".

Analyses

Proximate Composition of the Maize and Kidney Bean Composite Flour (%).Ingredients (G/100g): Samples of composite flour were chemically analysed to determine their moisture, crude protein, fat, fiber content, total ash and carbohydrate levels according to AOAC [6].

Functional Properties of Maize and Kidney Bean Composite Flour: The method of AOAC [7] was used to determine the bulk density, weight of 10 ml capacity graduated measuring cylinder was gently filled with the sample and the bottom of the cylinder was tapped on the laboratory bench several times until there was no further dimunition. The bulk density was taken as the weight of the sample divided by the volume of sample. The modified method of Abbey & Ibeh [8] was used to determine the water absorption capacity (WAC), OAC and swelling power. A known weight of flour samples was mixed (in a varl-whirl mixer) with 10ml of distilled water and allowed to stand for 30 minutes at ambient room temperature (28-29°C) before being centrifuged at 5,000 rpm for 30 minutes. Measuring out the volumes of the supernatants was used to find the volumes of the remaining absorbed liquids (water and oil). Multiplication of the respective absorbed volumes by the respective liquid density (mass/volume) was used to get the expression of the WAC and OAC in g liquid/g sample. The method of Abbey & Ibeh [8] was used to determine the gelation capacity of the flour samples. Samples suspension of 2-20% (W/V) was prepared in 5ml distilled water in test tubes. The test tube containing the suspensions was then heated for one hour in boiling water bath followed by rapid cold tap water cooling. The test tubes containing the samples were further cooled for two hours at 40C. The gelation concentration was determined as that concentration when the sample from the invented test tube did not fall or slip.

Pasting Properties of Maize and Kidney Bean Composite Flours: 2.5g of samples was weighed into a dried empty canister, then 25ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50 to 950C with a holding time of 2 min followed by cooling to 500C with 2 min holding time. Peak , trough, breakdown, final and set back viscosities as well as peak time and pasting temperature were read from the pasting profile with the aid of thermocline for windows software connected to a computer [9].

Antinutritional Factors of Maize and Kidney Bean Composite Flours: The method used for the determination of phytate given by Vaintraub & Lapteva [10] was used. Tannins, Folin-Denis spectrophotometric method as described by Pearson [11] was used. The trypsin inhibitor activity (TIA) assay was determined by Spectrophotometric method of Arntfield, et al. [12] also, Oxalate determination was by the method described by Nelson SS, et al. [13].

Sensory Scores: Randomly selected 20 screened and trained panelists who are conversant with TUWO eating quality were used to organoleptically assess the fresh experimental TUWO samples for mouth feel, flavour, appearance, colour and overall acceptability using the method of Iwe MO, et al. [14].

Statistical Analysis

Data obtained was subjected to Analysis of Variance (ANOVA) followed by Tukey's Least Significant Difference(LSD) test to compare treatment means; differences was considered significant at 95% ($P \leq 0.05$) (SPSS V21 software).

Results and Discussion

Proximate Composition (%) of Maize and Kidney Beans Flours

The proximate analysis of the maize and kidney bean data is depicted in Table 2, down the column, the moisture, protein, Ash and fiber content of the samples increased ($p<0.05$) significantly with increasing supplementation of kidney beans with maize flour. Their values ranged from (8.59-9.86, 6.82-11.63, 2.82-5.94 and 2.82-5.94)% while the crude fat and carbohydrate content decreased (P<0.05) significantly from 3.38-3.78 and 65.99-76.20 respectively. The results of the moisture, protein, ash content and fiber content fat and carbohydrate content are within the range for Ogi produced from composite flours of maize Ogi fortified with periwinkle meat flour blends reported by Ufot I, et al. [15], SON [16], Ezeama CF [17] reported that low moisture levels positively affect long shelf life of food as they discourage microbial proliferation that could lead to spoilage. In comparison to the Nigerian regulatory standards for moisture content values of whole Food the moisture contents of the current study were within regulatory specifications of moisture 40% maximum [16]. The consistent increased in protein content with increasing levels of kidney beans flour supplementation could be attributed to higher protein content in Kidney beans. Similar observations were reported by Aminigo & Akingbala [18], Aremu, et al. [19], Fasasi, et al. [20], Oluseyi, et al. [21] for maize fortified with groundnut flour, maize fortified with okra seed meal and maize ogi fortified with tilapia flour. Proteins do most of the work in cells and are required for the structure, function, and regulation of the body's tissues and organs [22]. The increase in the ash content of the composite flour maybe due to high ash content of kidney beans as compared to maize flour. The higher ash content in the fortified flours relative to 100% maize flour is an indication that kidney beans flour addition would contribute to higher mineral content in the TUWO. The increase in the fiber content of the composite flour maybe due to high fiber content of kidney beans as compared to maize flour. The decrease in the fat and carbohydrate content of the composite flours maybe due to low fat and carbohydrate content of kidney beans.

Samples	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate
A	$8.59^{a}\pm0.01$	$6.82^{a}\pm0.01$	$3.78^{d}\pm0.03$	$2.82^{a}\pm0.04$	$1.81^{a}\pm0.01$	$76.20^{e}\pm0.06$
B	$8.68^{b}\pm0.01$	$8.00^{b}\pm0.01$	$3.59^{c}\pm0.01$	$3.51^{b}\pm0.02$	$1.98^{b}\pm0.02$	$74.23^{d}\pm0.02$
C	$9.27^{c}\pm0.04$	$9.25^{c}\pm0.09$	$3.50^{b}\pm0.03$	$4.03^{c}\pm0.02$	$2.28^{c}\pm0.01$	$71.69^{c}\pm0.13$
D	$9.52^{d}\pm0.12$	$10.91^{d}\pm0.16$	$3.45^{b}\pm0.00$	$4.57^{d}\pm0.04$	$2.88^{d}\pm0.02$	$69.19^{b}\pm1.05$
E	$9.86^{e}\pm0.04$	$11.63^{e}\pm0.52$	$3.38^{a}\pm0.00$	$5.94^{e}\pm0.01$	$3.22^{e}\pm0.01$	$65.99^{a}\pm0.55$
LSD	0.07	0.66	0.06	0.40	0.08	0.09

Table 2: Proximate Composition of Maize and Kidney beans flours (%).Ingredients (g/100g).
Values are means standard of duplicate determinations
Means with same superscript in the same column are not significantly (p>0.05) different
LSD: Least Significant Difference
Keys: A = (100 % Maize flour control) B = (90 % Maize and 10% kidney beans flour) C = (85% Maize and 15% kidney beans flours) D (80% Maize and 20% Kidney beans flours), E (75% Maize and 25% Kidney beans flours)

Functional Analysis

The results of the functional properties of maize and kidney beans composite flours are showed in Table 3. The bulk density, water absorption and swelling capacities decreased (p<0.05) significantly, their values ranged from 0.60-0.86g/ml, 1.11-1.39ml/g and 2.44-3.07 respectively. The results of these values are within the range reported by Ufot I, et al. [15]. The observed decreased in bulk density with increased in kidney bean flour supplementation could be attributed to decrease in carbohydrate as the level of kidney bean flour increased. Similar observations were reported by Fasasi, et al. [20] for fermented maize and nile tilapia flour blends. The reduction in bulk density due to kidney beans flour supplementation would be an advantage in the formulation of children foods where high nutrient density to low bulk is desired [23,24]. Water absorption capacity determines flours consistency is dependent on the compositional structure of the sample [24,25]. The water absorption capacity obtained in this study for 100% maize flour (1.39) was higher than 0.67g/g reported by Alka, et al. [26] but lower than 1.12 - 1.46g/g reported by Beugre, et al. [27] for fermented maize flour this may be due to difference in variety. The decrease in water absorption with increasing levels of kidney beans flour addition could be an advantage because flours with low water absorption would provide more nutrients - dense foods [24]. Decreased in the swelling index could be due to weak bond forces in maize and kidney bean flours and reduction in the carbohydrate content of the composite flours [26]. The oil absorption capacity increased (p<0.05) significantly with varying amount of kidney beans supplementation with maize, the value of the oil Absorption capacity ranged from 0.77-0.93ml/g. The foaming and gelatinization capacity increased (p<0.05) significantly, from 2.79-3.85 and 8.01-13.07 respectively. This agrees with the result of Ufot I, et al. [15]. This could be attributed to increase in protein content in the blends with increasing levels of kidney bean flour supplementation. Sathe, et al. [28] noted that the ability of the flours to form foam depends on the presence of flexible protein molecules which may decrease the surface tension of water. The variation in gelation concentration could be attributed to the relative ratios of different constituents including proteins, carbohydrates and lipids in the flour samples Fasasi, et al. [20].

SAMPLES	Bulk density (g/ml)	Oil Absorption Capacity (ml/g)	Water Absorption capacity(ml/g)	Foaming capacity	Swelling Index	Gelatinization Capacity
A	0.86^{c}±0.01	0.77^{a}±0.01	1.39^{d}±0.01	2.79^{a}±0.01	3.07^{d}±0.01	8.01^{a}±0.01
B	0.81^{c}±0.01	0.80^{ab}±0.01	1.29^{c}±0.01	2.96^{b}±0.01	2.92^{c}±0.01	8.92^{b}±0.09
C	0.74^{b}±0.01	0.83^{b}±0.01	1.26^{bc}±0.01	3.19^{c}±0.04	2.89^{c}±0.01	10.05^{c}±0.01
D	0.70^{b}±0.03	0.89^{c}±0.01	1.21^{b}±0.01	3.40^{d}±0.01	2.66^{b}±0.01	10.08^{c}±0.01
E	0.60^{a}±0.01	0.93^{c}±0.02	1.11^{a}±0.01	3.85^{e}±0.04	2.44^{a}±0.01	13.07^{d}±0.03
LSD	0.06	0.05	0.06	0.16	0.04	0.04

Table 3: Functional properties of Maize and Kidney beans composite flours.
Values are means standard of duplicate determinations
Means with same superscript in the same column are not significantly ($p>0.05$) different
LSD: Least Significant Difference
Keys: A = (100 % Maize flour control) B = (90 % Maize and 10% kidney beans flour) C = (85% Maize and 15% kidney beans flours) D (80% Maize and 20% Kidney beans flours), E (75% Maize and 25% Kidney beans flours).

Pasting Analysis of Maize and Kidney Bean Composite Flours

The results of the pasting properties of maize and kidney beans flours are showed in Table 4. The (peak, trough, set back, final) viscosities and pasting temperature increased ($p<0.05$) significantly across the row as kidney beans flour increased. Results ranged from 239.55-265.50, 177.48-196.26, 135.58-200.61, 363.06-395.21 and 64.42-68.41 respectively. The results of these values are within the range reported by Idowu A [29]. That the final viscosities of the composite flours increased when he supplemented maize with African yam bean seed and Mbata, et al. [30]. Peak viscosity is an index of the ability of starch to swell freely before their physical break down [31]. Trough viscosity measures the ability of the paste to withstand break down during cooling [32]. The higher the setback viscosity the lower the retrogradation of the flour paste during cooling and the lower the staling rate of the product made from the flour [33]. The increase in final viscosity, gives a measure of the resistance of paste to shear force during stirring [31,34]. Pasting temperature is the temperature at which initial rise in viscosity occurs when starch granules and proteins begin to absorb water and swelled as the temperature increased [33]. The breakdown viscosity and peak time decreased down the row results ranged from 40.90-70.49.55 and 4.38-5.44 respectively. The results of these values are within the range reported by Idowu A, et al. [29], Mbata I, et al. [30]. Peak time is the measure of the cooking time [34].

Samples	A	B	C	D	E	LSD
Peak vel	239.55^{a}±0.65	240.58^{b}±0.57	241.93^{c}±0.01	255.72^{d}±0.38	265.00^{e}±2.66	
Trough vel	177.48^{a}±0.55	180.85^{b}±0.19	182.52^{c}±0.72	188.64^{d}±0.49	196.26^{e}±0.07	1.65
Brk vel	70.49^{e}±0.68	55.71^{d}±0.39	45.99^{c}±0.01	43.55^{b}±0.65	40.90^{a}±0.04	1.77
Final vel	363.06^{a}±0.05	365.59^{b}±0.56	370.48^{c}±0.61	390.65^{d}±0.44	395.21^{e}±0.04	2.00
Setback Vel	135.58^{a}±0.57	141.96^{b}±1.34	147.09^{c}±0.01	149.06^{d}±1.46	200.61^{e}±0.55	1.23
Peak Time	5.44^{d}±0.06	4.82^{c}±0.01	4.77^{c}±0.03	4.70^{b}±0.01	4.38^{a}±0.02	0.06
Peak Temp	64.42^{a}±0.09	65.37^{b}±0.01	66.95^{c}±0.05	67.16^{d}±0.09	68.41^{e}±0.02	0.09

Table 4: Pasting properties of Maize and Kidney beans composite flours.
Values are means standard of duplicate determinations
Means with same superscript in the same column are not significantly ($p>0.05$) different
LSD: Least Significant Difference
Keys: A = (100 % Maize flour control) B = (90 % Maize and 10% kidney beans flour) C = (85% Maize and 15% kidney beans flours) D (80% Maize and 20% Kidney beans flours), E (75% Maize and 25% Kidney beans flours).

Antinutritional Analysis of Maize and Kidney Beans Composite Flours

The Antinutritional analysis of the maize and kidney beans composite flour is shown in Table 5. Down the column the phytate content increased ($p<0.05$) significantly, there were also significant differences in the tannins, oxalate and TIA. Their values are 5.21-5.99 mg/100g, 3.84-4.80 mg/100g, 2.44-2.66 mg/100g and 0.99-1.21 respectively. Results support the claim [33-35]. Phytate are known to form complexes with iron, zinc, calcium and magnesium making them less available and thus inadequate in food samples especially for children however, the phytate content are far lower than the minimum amount of phytic acid reported by Siddhuraju p, et al. [36] to hinder the absorption of iron and zinc. It is known that 10-50 mg phytate per 100g will not cause a negative effect on the absorption of zinc and iron. The reduction in the tannin content maybe due to hydrolysis of tannins by enzyme into lower inositol phosphate which are believe to be activated during the soaking process by organism (yeast). Oxalate is known to form complexes with calcium to form insoluble calcium -oxalate salt. Siddhuraju p, et al. [36] reported a safe normal range of 4-9 mg/100g for oxalates. The oxalate content of the composite flour was far lower than the reported value. Protease inhibitors such as trypsin inhibitor activity (TIA) in diets lead to formation of irreversible trypsin-enzyme inhibitor and subsequently indigestibility of dietary protein, thus leading to slower growth in people especially children [37].

Samples	Phytate	Oxalate	Tannins	TIA
A	$5.21^{a}\pm0.01$	$2.66^{b}\pm0.02$	$4.80^{c}\pm0.01$	$1.21^{d}\pm0.01$
B	$5.63^{b}\pm0.02$	$2.65^{b}\pm0.02$	$4.68^{b}\pm0.01$	$1.14^{c}\pm0.01$
C	$5.75^{c}\pm0.05$	$2.61^{b}\pm0.01$	$5.38^{e}\pm0.01$	$1.13^{bc}\pm0.01$
D	$5.97^{d}\pm0.01$	$2.49^{a}\pm0.01$	$4.88^{d}\pm0.01$	$1.08^{b}\pm0.01$
E	$5.99^{d}\pm0.01$	$2.44^{a}\pm0.02$	$3.84^{a}\pm0.05$	$0.99^{a}\pm0.01$
LSD	0.03	0.06	0.07	0.06

Table 5: Antinutrients analyses of Maize and Kidney beans composite flours.
Values are means standard of duplicate determinations
Means with same superscript in the same column are not significantly ($p>0.05$) different
LSD: Least Significant Difference
Keys: A = (100 % Maize flour control) B = (90 % Maize and 10% kidney beans flour) C = (85% Maize and 15% kidney beans flours) D (80% Maize and 20% Kidney beans flours), E (75% Maize and 25% Kidney beans flours).
Keys: A = (100 % Maize flour control) B = (90 % Maize and 10% kidney beans flour) C = (85% Maize and 15% kidney beans flours) D (80% Maize and 20% Kidney beans flours), E (75% Maize and 25% Kidney beans flours).

Sensory Scores of TUWO from Maize and Kidney Beans Composite Flours

Table 6 gives the sensory Scores of TUWO samples, down the column, the mouth feel, aroma, texture and appearance increased ($p<0.05$) significantly. Results ranged from 3.95-8.45, 4.25-8.60, 3.75-8.60 and 5.70-8.20 respectively. Results is in arrangement with the work of Olanipekun O, et al. [38], Otunola ET, et al. [39]. Mouth feel is an important sensory attribute of any food. Samples from pure blend of 80: 20 and 75:25 maize and kidney beans, showed high sensory scores on Mouthfeel. However, some panelists still expressed liking for the other samples. This observation may be attributed to personal (physiology) of choice or an influence of the experimental conditions. The high aroma scores implies that the addition of the kidney bean flour in the production of TUWO improved the aroma of the food. The panellists' preference for the control sample in terms of texture over other samples may be due to increase in the concentration of kidney bean flour in the other samples, which may have influenced the texture of the samples negatively contrary to what they know. The panellists' preference for the control in terms of appearance sample over other samples made from the composite flours may be due to the alteration in the physical properties of the TUWO due to the inclusion of kidney bean flour. Edema, et al. [40] got a similar result and reported that addition of soy flour to maize flour in the production of sour maize bread affected the physical properties. The overall acceptability is inclusive of all sensory attributes: Mouthfeel, aroma, texture and appearance. The scores of the overall acceptability shows that the food sample C with the mean score (8.70) was most preferred over other samples made from composite maize and kidney bean flours. The control sample A was least accepted by the panelists. This result indicates that addition of kidney bean flour to maize flour for TUWO processing increased the consumer acceptance of the product. This is in agreement with past works by Mbata I, et al. [30], Otunola ET, et al. [39], Edema MO, et al. [40] in which consumers were reported to prefer products made from composite mixtures of legume and maize to products from 100% maize flour. In this report, the most accepted product (Sample C) was made from maize flour and kidney bean flour at the ratio 85:15.

Samples	Mouthfeel	Aroma	Texture	Appearance	Overall accp.
A	$3.95^{a}\pm1.36$	$4.25^{a}\pm1.25$	$8.60^{e}\pm0.68$	$8.20^{e}\pm0.62$	$4.45^{a}\pm1.15$
B	$4.75^{b}\pm1.12$	$6.05^{b}\pm0.39$	$6.50^{d}\pm1.57$	$6.90^{d}\pm0.79$	$7.70^{d}\pm0.47$
C	$5.65^{c}\pm0.81$	$6.85^{c}\pm1.09$	$6.00^{c}\pm1.81$	$6.60^{c}\pm0.94$	$8.70^{e}\pm0.47$
D	$5.65^{c}\pm0.59$	$7.55^{d}\pm0.69$	$4.95^{b}\pm1.79$	$5.90^{b}\pm1.12$	$7.40^{c}\pm0.94$
E	$8.45^{d}\pm0.76$	$8.60^{e}\pm0.68$	$3.75^{a}\pm1.52$	$5.70^{a}\pm1.38$	$5.25^{b}\pm1.07$
LSD	0.02	0.55	0.21	0.10	0.20

Table 6: Sensory Analyses of TUWO from Maize and Kidney Beans composite flours.
Values are means standard of duplicate determinations
Means with same superscript in the same column are not significantly (p>0.05) different
LSD: Least Significant Difference

Conclusion

The study was able to develop composite flour from maize and kidney beans for TUWO which were able to meet the functionality of raw material which determine product quality and process effectiveness. Also, the proximate, functional, pasting, Antinutritional factors as well as sensory properties were examined. TUWO produced have increased nutrients which are desirable for good health and wellbeing. This would provide nutritious food to combat malnutrition problems of all aged group in developing countries and enhanced food security. From the research, supplementation is hereby recommended to improve the nutritional quality of TUWO.

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