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Physical and sensory quality of extruded instant millet-soybean-cowpea porridge flour

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Abstract:
Background: *Pearl millet, one of the most important cereal grain which is underutilized in Africa can be used to produce complementary foods which help reduce malnutrition in children. Production of extruded pearl millet- based complementary foods improves physicochemical properties of the complementary foods which helps improve the nutritional value, acceptability and convenience. The aim of this study was to develop and determine the physical and sensory quality of pearl millet (Pennisetum glaucum)-based extruded instant complementary porridge flour for use by children.*
Material and Methods: *In this study, Native and improved varieties of pearl millet complemented with soybeans (Glycine max) and cowpeas (Vigna unguiculata) were extruded, milled to obtain instant porridge flour. The physical and sensory quality of four samples of Shibe pearl millet: soybeans: cowpeas ratio of 100:0:0 (plain), 90:5:5, 80:15:5 and 70:25:5 and four samples of native millet: soybeans: cowpea ratio of 100:0:0, 90:5:5, 80:5:15 and 70:5:25 were evaluated.*
Results: *The bulk density of the flours ranged from 1.6 to 2.0 g/cm^3; viscosity from 130 to 480 mPas; water absorption index from 3.6 to 4.3 g/g and; water solubility index from 22.4 to 38.1%. The sensory evaluation of the porridge samples indicated that all porridges were accepted.*
Conclusion: *This study indicated that extrusion and complementation of pearl-millet with soybeans and cowpeas improved the physical and sensory qualityof pearl millet porridge.*
Keywords: *Pearl millet; extrusion; instant porridge flour; physical quality; sensory quality.*

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I. Introduction

Among millets species, pearl millet is the most widely grown and is currently the world's sixth most important cereal grain (Ramashia et al., 2021). It is a good source of dietary fibre, vitamins, minerals, proteins and phenolic compounds as compared to most traditional consumed cereals (Krishnan & Meera, 2018). It is a staple food in Africa and many other developing countries where it is used to make flour, bread, porridge and several other local beverages (Obomeghei et al., 2021).The physical properties of grains such as millets play a very important role in the quality of the final products such as flours (Surpam et al., 2019).The physical quality of pearl millets is normallylow, however processing operations such as extrusion tend to improve physical quality, improving convenience and acceptability (Florence & Asna, 2017;Liu et al., 2021). The availability of ready-to eat pearl millet products reduces the time spent by mothers to prepare porridges for complementary feeding with improved physical quality.According to Nani and Krishnaswamy (2021), the physical quality parameters such aswater holding, water solubility and bulk density influence the acceptability of products by consumers. Extrusion being a versatile efficient processing technology improves both nutritional and functional properties of products which help improve the convenience of productsdue to the changes that takes place in the nature of protein, starches and other constituents of food products(Shelar & Gaikwad, 2019).The physical and sensory properties of plant-based complementary foods for infants are indirectly of nutritional significance as they impact the quantity of food eaten and invariably, the nutrient intake (Amagloh *et al.*, 2012; Prakash et al., 2019)

Consumers'' acceptance of most of the extruded foods is mainly due to the convenience, attractive appearance and texture of products (Alemayehu et al., 2019). Among the drawbacks of industrial food use of whole-grain pearl millet flour include unpleasant sensory characteristics and limited storage life (Onyeoziri et al., 2021). According to Sobowale et al. (2021), due to rapid urbanization in developing countries, the demand for convenience-type products along with health-promoting effects and appealing sensory attributes is high.The availability of complementary foods in ready-to-eat form improves convenience during preparation and extrusion improves sensory quality for infants and young children hence favoring complementary feeding.Sensory characteristics such as taste, appearance, freshness, texture, colour and smell are essential factors driving consumers towards shopping and consumption of convenient food products (Yi et al., 2022).Extrusion cooking of whole-grain pearl millet flour has significant influence on the physical and sensory quality which can help in the acceptability of pearl millet-based complementary foods which can help reduce the prevalence of under-nutrition in developing countries like Tanzania (Sobowale et al., 2021; Yi et al., 2022; Ogbo et al., 2018).

II. Materials and Methods

Samples: Two pearl millet varieties (improved variety *Shibe* and native variety) and cowpeas were obtained from Hombolo Agricultural Research Institute in Dodoma, while soybeans were obtained from Morogoro municipality central market, Tanzania.

Instant flour preparation: Millet and cowpeas were sorted and washed while soybeans were sorted and dehulled and air oven dried at 60ºC. The conditioned grains (20% moisture) were extruded using a twin screw extruder (Kneader Model EX 60, Chaoyuan Power Machinery. Co. Ltd, Yantai, China). The extruder zone temperatures were 141 and 105ºC in zone I and zone II, respectively; screw and feeder speed were 30.45 and 6-8 rpm, respectively. The extrudates were allowed to cool down at room temperature before milling into flour (sieve size-1mm). The flours were mixed in appropriate composite flour formulations (Table 1) using Nutrisurvey software (http://www.nutrisurvey.de/) and stored in polyethylene bags for analysis**.**

Sample formulation: The flour samples were mixed in proportions which provided the highest amino acid score (>65%) proportions which meet the FAO/WHO/UNU (1985) requirements for essential amino acids and energy for young children and infants. Eight samples of formulations were made from the two varieties of pearl millet and the composition (Table 1) was based on the output of nutrisurvey (http://www.nutrisurvey.de/).

Table 1: Pearl millet-soybean-cowpeas based complementary food formulations (g/100 g)

Millet variety	%Millets	%Soybeans	%Cowpeas	Total
Shibe(improved)	100	0	0	100
	90	5	5	100
	80	15	5	100
	70	25	5	100
Native	100	0	0	100
	90	5	5	100
	80	5	15	100
	70	5	25	100

Analyses

Physical quality: Bulk density (BD) of the flour samples were determined by the procedure described by Stojceska et al. (2008). Water solubility index (WSI) and water absorption index (WAI) were determined by using the procedure for cereals as described by Anderson et al. (1969) and viscosity of the porridges was determined by using HAACE Viscotester 2plus (Thermo-electron company, Karlsruhe, Germany).

Sensory quality: Sensory evaluation was carried out according to the procedure described by Meilgaard et al. (2006)by 60 panelists. Consumer testing involved breastfeeding mothers at Sokoine University of Agriculture hospital. Quantitative descriptive analysis was carried out by using eight trained panelists at Sokoine University of agriculture,Department of Food science and Agro-processing. The porridges were prepared by adding hot water to instant porridge flour(flour: water; 1:5 w/v)The panelists evaluated sensory quality based on colour, aroma, texture, taste and overall acceptability using a nine-point hedonic scale (1= dislike extremely to 9=like extremely).

Statistical analysis: One way-Analysis of variance (ANOVA) was used for statistical analysis and Duncan's Multiple Range Test for significant difference between means ($P < 0.05$) for physical properties and sensory evaluation data. Principal Component Analysis (PCA) was done using R-software to analyze the correlation loadings between panelist's (trained and untrained) liking of the samples.

III. Results and Discussion

Physical quality

Table 2. Physical qualityof millet-soybean-cowpea instant porridge flour

Sample	**Bulk density(g/cm^3)**	**WSI (%)**	**WAI(g/g)**	**Viscosity(mPas)**
Shibe millet plain(100:0:0)	2.0 ± 0.00^{bd}	33.9 ± 1.7^{bf}	3.8 ± 0.2^{bd}	475 ± 7.07^{a}
Shibe-soybean-cowpeas(90:5:5)	2 ± 0.08^{bd}	38.1 ± 6.4^{bcd}	3.7 ± 0.1^{a}	200 ± 0.00^{b}
Shibe-soybean-cowpeas(80:15:5)	1.9 ± 0.01^{bd}	34.6 ± 0.3^{bf}	3.6 ± 0.1^{b}	140 ± 0.00^{c}
Shibe-soybean-cowpeas(70:25:5)	1.7 ± 0.00^{cd}	27.2 ± 6.5^{bf}	3.6 ± 0.0^{c}	180 ± 0.00^{d}
Native pearl millet plain(100:0:0)	1.6 ± 0.04^{bed}	28.0 ± 2.9^{bf}	4.2 ± 0.3^{bd}	215 ± 7.07^{e}
Native-soybean-cowpeas(90:5:5)	1.7 ± 0.07^{bed}	27.7 ± 1.5^{bf}	4.2 ± 0.1^{bd}	130 ± 0.00^{f}
Native pearl millet-soybean-cowpeas(80:5:15)	1.7 ± 0.03^{bed}	22.4 ± 8.4^{cd}	4.3 ± 0.3^{bd}	150 ± 0.00^{g}
Native pearl millet-soybean-cowpeas(70:5:25)	1.7 ± 0.00^{bed}	24.1 ± 1.4^{bf}	4.3 ± 0.3^{bd}	140 ± 0.00^{h}

Values are expressed as mean± standard deviation at two replications. The mean values with different superscript letters along the column are significantly different (P<0.05).

Bulk density: Bulk density is a very important parameter in the production of extruded products (Pardhi et al., 2019). Density of extrudates is a measure of expansion that occurred during the extrusion process (Filli et al., 2013). The bulk density as shown in (Table 2), ranged from 1.6g/cm^3 in native: soybean: cowpea flour (100:0:0) to 2.0g/cm^3 in *Shibe*: soybean: cowpeas (100:0:0). The highest bulk densities were observed in plain *Shibe* millet flour and *Shibe*: soybeans: cowpeas (90:5:5). The highest bulk densities were observed with increased proportion of pearl millet. Similar results were reported by Chandra and Kumari (2015) that the incorporation of cereals such as rice (rich sources of starch) into wheat flour increased the bulk density. This study indicated that extrusion improved the bulk density of porridge flour. Extruded pearl millet based flours had higher than raw pearl millet flours. Gull et al. (2021) reported that the density of pearl millet flours ranged from 1.36 - 1.79 g/cm^3. The flours from the improved pearl millet had higher bulk densities as compared to those formed from the native variety of pearl millet. Higher bulk densities indicated that flours could be used as thickeners and are suitable for infant's foods.

Water solubility index: Water solubility index is an indicator of macromolecules (such as starch) degradation (Tadesse et al., 2019). It measures the amount of soluble components released from starch after extrusion and higher water solubility index is an indicator of good starch digestibility as it implies the extent of gelatinization and dextrinization (Yousf et al., 2017). It can be used as a measure of starch conversion which occurs during extrusion (Pardhi et al., 2019). Starch gelatinization is the process of breaking down the intermolecular bonds of starch molecules in the presence of water and heat allowing the hydrogen bonding sites to engage more water increasing the starch solubility (Kadam et al., 2015).

The water solubility index (WSI) of the composite flours ranged from 22.4% to 38.1% (Table 2). The highest WSI was observed in *Shibe* millet: soybeans: cowpeas (90:5:5). In all the formulations from two millet varieties, WSI values were lowest in flours with highest amount of legumes (soybeans and cowpeas). WSI depends on the changes that occurs into starch due extrusion (Oikonomou and Krokida, 2012) thus decrease in the amount of millets (starch source) led to the decrease in WSI. This study also indicated that extrusion improved WSI of pearl millet flour as the WSI values of extruded flours were higher significantly higher at ($p < 0.05$)than those of raw pearl millet flour

Water absorption index: Water absorption index (WAI) is a measure of the volume occupied by the starch granule after swelling in excess water (Rathod and Annapure, 2017; Yousf et al., 2017). It is the amount of water (moisture) taken up by food/ flour to achieve the desired consistency and create quality food product (Awuchi et al., 2019). It depends on the availability of hydrophilic groups that bind water molecules (Pardhi et al., 2019).

The water absorption index ranged from 3.6 to 4.3 g/g (Table 2). There was a significant difference ($p<0.05$) in WAI between formulations made from two varieties of pearl millet. There was a significant difference ($p<0.05$) in WAI for the complementary flours made from the improved variety of pearl millet while no significant difference in the WAI for the complementary flours made from the native variety of pearl millet. The native pearl millet based complementary flours were higher in the WAI as compared to the improved pearl millet based formulations.

Viscosity: The viscosity of the product affects both the preference and acceptance hence it is important when producing child foods to produce a product with good viscosity (Konst et al., 2017). It is an important attribute even in commercial based-food formulas to improve both quality and acceptability of the product (Hron & Rosen, 2020).

The viscosity of the instant porridges ranged from 130mPas in native pearl millet-soybean-cowpeas (70:5:25) to 475mPas in non-complemented *Shibe* millet porridge (Table 2). There was a significant difference ($p<0.05$) in viscosity of the porridge prepared from the two varieties of pearl millet. Improved pearl millet- based composite flours had higher viscosity than the native based composite flour porridge. The viscosities were lower as compared to the recommended consistency for feeding children which according to Amagloh. (2022) ranges from 1000-3000mPas.

Table 3. Acceptability of millet-soybean-cowpea instant porridge

Sample	Colour	Aroma	Texture	Taste	General acceptability
Shibe millet	$6.8{\pm}0.86^{bd}$	$6.7{\pm}1.29^{ac}$	$7.1{\pm}1.41^{dc}$	$6.3{\pm}1.55^{bef}$	$6.7{\pm}1.15^{a}$
Shibe-soybean-cowpeas(90:5:5)	$6.6{\pm}1.07^{bd}$	$6.7{\pm}1.48^{ac}$	$6.7{\pm}1.49^{dc}$	$6.2{\pm}1.14^{bef}$	$6.5{\pm}1.14^{a}$
Shibe-soybean-cowpeas (80:15:5)	$6.6{\pm}1.13^{a}$	$6.9{\pm}1.48^{bc}$	$6.7{\pm}1.51^{dc}$	$6.8{\pm}1.45^{bdf}$	$6.9{\pm}1.04^{a}$
Shibe-soybean-cowpeas(70:25:5)	$7.4{\pm}0.82^{c}$	$7.4{\pm}1.16^{bc}$	$7.3{\pm}1.18^{dc}$	$7.8{\pm}1.09^{bcd}$	$7.8{\pm}1.06^{c}$
Native pearl millet	$6.3{\pm}0.89^{ac}$	$6.6{\pm}1.10^{b}$	$6.4{\pm}1.31^{ab}$	$6.1{\pm}1.27^{a}$	$6.8{\pm}0.71^{b}$
Native millet-soybean-cowpeas(90:5:5)	$6{\pm}1.13^{ac}$	$6.3{\pm}1.01^{ad}$	$7{\pm}1.52^{ab}$	$6{\pm}1.62^{a}$	$6.5{\pm}1.10^{d}$
Native millet-soybean-cowpeas(80:5:15)	$5.9{\pm}1.11^{ac}$	$5.7{\pm}1.29^{c}$	$6{\pm}1.62^{cd}$	$6{\pm}1.62^{a}$	$6.1{\pm}0.87^{e}$
Native millet-soybean-cowpeas(70:5:25)	$5.4{\pm}1.35^{ck}$	$6.5{\pm}1.19^{ad}$	$5.9{\pm}1.29^{ab}$	$5.9{\pm}1.29^{a}$	$5.9{\pm}1.17^{f}$

The values are expressed as mean± standard deviation (n=30). The mean values with different super scripts along the same column are significantly different at $P<0.05$.

Colour: Colour in many cases acts as a trigger for acceptance of products by the consumers as it plays an important role in visual recognition and assessments of the surface and subsurface properties of the food (Devrajan et al., 2018). It also acts as one of the triggers for acceptance of snack foods and extruded products (Chakraborty et al., 2014). The colours of the extrudates are largely affected by the feed matrix composition and the process condition used in the preparation of the products (Dalbhagat et al., 2019).

The sensory evaluation (Table 3) indicated that there was a significant difference($p <0.05$)in acceptability of colour of the formulations made from improved pearl millet variety and those made from native pearl millet variety. The results indicated that the acceptability of colour ranged from 5.4 (native millet: soybean: cowpea (70:5:25) to 7.4 (*Shibe*: soybean: cowpeas (70:25:5). The acceptability of the colour of improved pearl millet based formulations was high as compared to that of native pearl millet based formulations.

Aroma: Aroma perception is a determinant factor in food choices and acceptability by consumers (Gierczynski et al., 2011). It is one of the sensory characteristics which is considered as a key area in which manufacturers can successfully use to differentiate their products to help enhance their acceptability (Maina, 2018).

The results (Table 3) indicated that there was a significant difference in the acceptability of the porridge made from the two varieties of pearl millet. The aroma acceptability ranged from 5.7 (native millet: soybean: cowpeas (80:5:15) to 7.4 (*Shibe*: soybean: cowpeas (70:25:5). The aroma of the improved pearl millet based formulations was highly accepted as compared to that of the native pearl millet based formulations. The aroma and taste of all samples of the flours were accepted by the panelists.

Texture: The results indicated that there was a significant difference ($p <0.05$) in acceptability of the texture of the porridges formed from two varieties of pearl millet. The acceptability of the texture of the porridges ranged from 5.9 (native millet: soybean: cowpeas (70:5:25) to 7.3 (*Shibe*: soybean: cowpeas (70:25:5) (Table 3). The improved-based formulations were most acceptable than native pearl millet based formulations.However, the texture of all the porridges formulations was acceptable.

Taste: The results indicated that there was a significant difference ($p<0.05$) in the acceptability of taste between the formulations made from improved pearl millet and those made from the native pearl millet variety

The tastes of formulations were liked by all the panelists (Table 3). However, there was a significant difference ($p <0.05$) in acceptability of the tastes between the formulations formed from two varieties of pearl millet. The taste ranged from 5.9 (native millet: soybean: cowpea (70:5:25) to 7.8 (*Shibe*: soybean: cowpeas (70:25:5).

General acceptability: All formulations were accepted by the panelists (Table 3). However, higher acceptability was observed in the improved pearlmillet-based formulations while native pearlmillet-based formulations were liked slightly. The overall acceptability ranged from 5.9(native millet: soybean: cowpeas (70:5:25) to 7.8 (*Shibe*: soybean: cowpeas (70:25:5). The results indicated that although all attributes of the formulations of complementary flours were accepted, taste and texture were highly accepted by the panelists than the other attributes of the samples.

Preference mapping: Preference mapping was used to establish the correlation between panelists, samples and the associated sensory attributes.

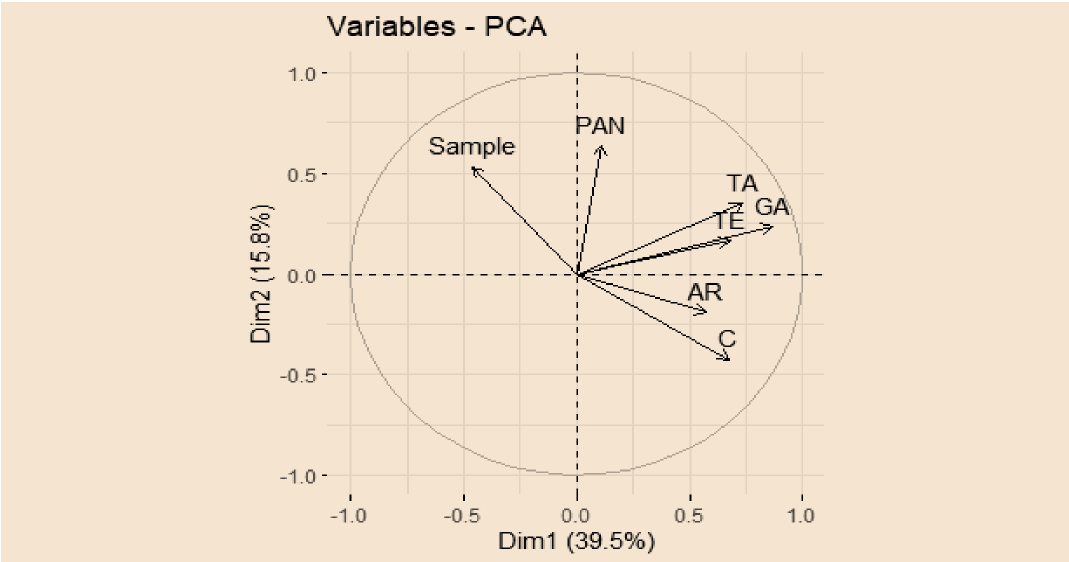

Figure 1. Correlation loadings of sensory data for quantitative descriptive analysis and consumer tests where PAN; Panelists, TA; Taste, GA; General acceptability, AR; Aroma, TE; Texture and C; Colour

The principal component 1 (PC1 or Dim 1) explained 39.5% of the variation between variables of quantitative descriptive analysis (QDA) and consumer liking of the samples while Principal component 2 (PC2 or Dim 2) explained 15.8% of variation between variables. The results indicated that there was a positive correlation between tastes, texture, and generalacceptability (Figure 1). There was negative correlation between samples and aroma and colour. According to the PCA, the consumer liking of the samples was influenced mostly by taste, texture, aroma and least by the colour of samples. The colour of the samples was least liked in comparison with other sensory attributes, especially in the native millet-based formulations.

IV. Conclusion

This study indicated that extrusion and complementation of pearl-millet with soybeans and cowpeas improved the physical quality of the instant flour and sensory quality of pearl millet porridge. The instant porridge flour, that is convenient for preparation of porridge, anywhere, anytime, without further heating, would be suitable for use as complementary food. This might also be important for value addition, diversification and commercialization of under-utilized pearlmillet.

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