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Influence of Malting and/or Fermentation on Proximate Composition of FARO 44 Rice Plus Soybean Based Complementary Foods

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Abstract

Nutritional challenges around the globe are still on the increase, the use of appropriate and adaptable technologies to formulate an acceptable diet would mitigate suffering affecting especially vulnerable children. The objective of the study was to examine how malting and/or fermentation would influence the proximate composition of FARO 44 and improve its subsequently formulated rice-based complementary foods. Malting of rice was achieved by standard methods while accelerated natural fermentation was by back slopping. The proximate composition of formulated food products was evaluated. Four complementary products comprising non-mated non-fermented rice plus soybean (NMNFRS), malted non-fermented rice plus soybean (MNFRS), non-malted fermented rice plus soybean (NMFRS) and malted and fermented rice plus soybean (MFFRS) were formulated to provide 16 g protein/100 g each based on the proximate composition of the rice and soybean in food materials. Results of the proximate composition of formulated food products were within the recommended level of FAO except in terms of fat. Fermentation caused a slight increase in protein, fat, carbohydrate, energy value and slightly reduced ash, crude fibre and moisture. Malting caused a slight increase in fat and reduced ash and crude fibre. Formulated food products from malted and/or fermented rice plus soybean flour are adequately acceptable and hold potential application as complementary foods for addressing protein energy malnutrition (PEM), especially in children.

Keywords: Infant foods, Breastfeeding, Diet, Malt, Malnutrition

INTRODUCTION

The World Health Organization (WHO, 2002) advocated exclusive breastfeeding of infants for up to six months. However, this is not feasible in some sub-Saharan regions (Okonkwo *et al*., 2022), due to the poor health and nutritional status of most mothers. Similarly, the

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engagement of these mothers in market and farming activities is another influential factor affecting exclusive breastfeeding (Okonkwo *et al*., 2022). Most of these mothers therefore resort to complementary feeding of infants using a diet containing inadequate protein and energy (Anderson *et al*., 2001; Badau *et al*., 2016).

Complementary foods are those foods given mainly to infants to support breast milk (Bristone *et al*., 2021). They are mainly semi-solid or fluid foods which can also be given to the sick, invalids, and children to complement staple diets (Bristone *et al*., 2021). Traditional complementary foods include *tuwo*, *ogi* (*akamu*), *agidi*, *kunu* (*koko*) and other cereal basal porridges (Onofiok and Nnanyelugo, 2003). The major problems with these local complementary foods include low protein contents (quantity and quality) hence high incidence of protein energy malnutrition (PEM), high bulk hence low nutrient density, and high pH hence susceptibility to toxigenic microbial contamination and spoilage (Mosha and Svanberg, 1983: Rosenberg *et al*., 2015).

Due to increased home and industrial demands for rice in Nigeria for food production and consumption, more than fifty rice varieties including FARO 44 have been bred (Udemezue and Agwu, 2018; Ebenehi and Ahmed, 2019; Idu *et al*., 2021). Udemezue and Agwu (2018) and Ebenehi and Ahmed (2019) reported that Federal Agriculture Research Oryza (FARO 44) originated from Taiwan. FARO 44 is an interspecific hybrid between the local African and Taiwan rice, which has a cultivar name SIPI692033 and national code as NGOs-9144. The figure: 44 signified the number 44th among the released varieties in 1992. FARO 44 is an irrigated, favourable rain fed lowlands rice collectively developed by the West Africa Rice Development Association (WARDA), International Institute of Tropical Agriculture (IITA) and National Cereal Research Institute (NCRI). Several authors such as Udemezue and Agwu (2018), Ebenehi and Ahmed (2019) and Idu *et al.* (2021) have shown prominent qualities of FARO 44 desired by farmers and consumers over other rice grains. Studies by some researchers such as Lee *et al*. (2012), Pengkumsri *et al*. (2015), Danbaba *et al*. (2017), Bristone and Jibrilla (2017) and Verma and Srivastav (2017) have shown that rice can be used to formulate diet with acceptable quality because of its high lysine content, high level of digestibility, low anti-nutrients, free gluten and high sensory ratings compared to other cereals. According to other reports, rice is useful and effective for the management of maternal health and damaged liver (Roy *et al*., 2011; Lee *et al*., 2012). For example, in India, rice is considered a grain of life because of its application in human therapy and nutrition (Ray *et al*., 2016). Global interest in cereal-based fermented products has been increasing over the years due to their adaptable production technology, health and nutritional promoting aspects (FRGE, 2011; Ray *et al*., 2016). Reports by Olatoye (2011) and Danbaba *et al*. (2016) indicate that nearly two-thirds of the world's population uses rice as a staple food material. Rice has been reported as suitable for the production of a wide variety of food products (Gupta *et al*., 2010; Roy *et al*., 2011; Davies, 2015; Faltermaier, 2015; Ray *et al*., 2016; Danbaba *et al*., 2017; Bristone and Jibrilla, 2017). However, rice is low in protein quantity and quality as the sole complementary food. However, it can be complemented with plant sources of protein such as soybean (Chaudhari *et al*., 2018).

Malting and fermentation are established locally adaptable technologies for bulk reduction and food preservation. These technologies have been reported to increase the nutrient density of food (Mosha and Svanberg, 1983; Magala *et al*., 2015; Mantanjevic *et al.,* 2017). Complementation of low-protein diets with readily available and cheap plant protein sources e.g., soybean has been adequately established for maize, sorghum, millet, and other starchy staples by research workers (Badau *et al*., 2016; Chinelo *et al*., 2017). However, there is limited information on the processability of FARO 44 and soybean-based complementary foods especially as influenced by malting and/or fermentation. Therefore, complementing malted and/or fermented rice with soybean will holds the potential for increasing the utilization of the crops and addressing nutritional challenges faced around the globe.

MATERIALS AND METHODS

Sources of Raw Materials, Preliminary Handlings, Processing Operation and Formulations

FARO 44 was obtained from the National Cereals Research Institute, Badeggi, Bida, Niger State, while soybean (*Glycine max*) was procured from Gire Market, Gire Local Government, Adamawa State. The paddy was destoned in a mechanical de-stoner (De-Stoner, Hunan Sunfied Machinery Co., Ltd, Model: TQS 320, China) as described by Danbaba *et al*. (2019) while the soybeans were sorted manually to remove contaminants. Each raw material was purchased in clean jute bags and used promptly for the studies.

Soybean flour was processed as described by Badau *et al*. (2016) while paddy was divided into two equal lots. The first lot was malted while the second lot was left un-malted as described by Ariahu *et al*. (1999) and Bristone *et al*. (2021). Malting of paddy was carried out with some slight modifications. Paddy was washed twice with clean water. The cleaned paddy rice was steeped inside sufficient clean water to cover the surface of the grains completely. It was kept at 29 ± 2 ^{o}C with good air circulation for 24 hours. The steeping process was interrupted after every 6 hours by draining. An "air-rest" period of one hour each for every interruption was provided until the grain reached about 42% moisture content (Hough, 1992; Bristone *et al*., 2021).

The steeped paddy was then drained and wrapped in a wet jute bag to provide about 3 to 5 cm depth. FARO 44 grain was germinated for 43 hours at 29 ± 1 ^{o}C. The short period of germination was timed and was done to counter technical difficulties during dehulling of malted rice as experienced during pre-trials. After drying of germinated grains at 29 ± 2 ^{o}C under constant air circulations and turning of paddy for 48 hours, the germinated dried grains were polished by detaching the roots and rootlet (Bristone *et al*., 2021).

Each lot was de-husked by a Greep Rice Mill (Model-MBLN-115, China). The malted and non-malted paddy were dried at 40 ^{o}C in an air draft oven (air flow rate 140, Oven BS, Model OV-160, Gallen kamp, England) and de-husked. Then all the rice (malted and un-malted rice) was milled using a hammer miller (into flour) and let to pass through a 0.8 mm sieve (Christy Hunt Agricultural Ltd, Foxhills Ind. Est Scunthorpe, Model DE DN15 8QW, South Humbers, England) as described by Badau *et al*. (2016) and Bristone *et al.* (2021). The rice flours obtained from malted and non-malted rice were each divided into two sub-lots. A sub lot of each was fermented. The fermented products were spread on drying trays and dried in an air draft oven for about 2 hours at 40 ^{o}C using an airflow safety thermostat oven (air flow rate 140, Oven BS, Model OV-160, Gallen kamp, England) as described by Ariahu *et al*. (1999) and Bristone *et al.* (2021).

A 2 x 2 completely randomized within and between experimental design as described by Gomez and Gomez (1983) were employed for the study. The design comprised of malted and non-malted paddy rice and fermented and non-fermented milled rice that yielded four test samples which were each combined with soybean flour to target 16 g protein in each product.

The product formulation aimed at obtaining 16 g protein of each test product is shown in Table 1. The various amounts were obtained by materials balance (Figure 1) (Rao, 2010) based on the proximate compositions of the food materials to comply with recommendations of the protein advisory group (PAG) as described by World Food Programme (2021). The flours at appropriate ratios were blended in a dry mixer, parked in self-sealing polythene bags and placed in dry and cleaned plastic containers which were stored on dry shelves. The formulations were used within 1 week of production for the various experiments.
These are the amount of rice and soybean used in the mixing ratio that yielded 16 % protein. The same equation was also used for calculating the appropriate ratios of solid materials of the other samples.

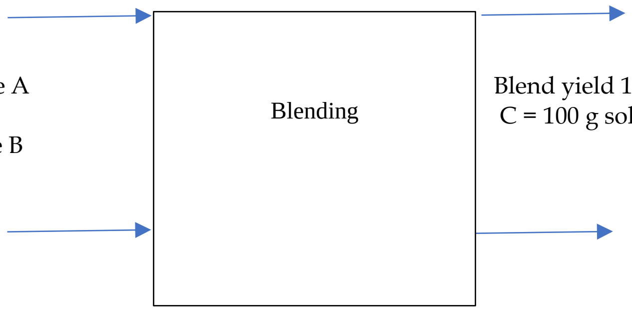
Table 1: Rice and Soybean Flour Mixtures for 16 g Protein/100 g

	Feed weight (g)					
Product flour	NMNFR	MNFR	NMFR	MFR	S	Protein g/100 g
NMNFRS	75.8	0	0	0	24.2	16
MNFRS	0	75.6	0	0	24.4	16
NMFRS	0	0	76.8	0	23.2	16
MFRS	0	0	0	78.0	22.0	16

NMNFRS = Non-Malted - Non Fermented FARO 44 Rice + Soybean flour, MNFRS = Malted - Non Fermented FARO 44 + Soybean flour, NMFRS =Non Malted – Fermented FARO 44 Rice + Soybean flour, MFRS = Malted – Fermented FARO 44 Rice + Soybean flour, S = soybean flour.

Let soybean with 39.43 g protein be A

Let FARO 44 with 8.60 g protein be B



Blend yield 16% protein
C = 100 g solids

Figure 1: Material balance.

Equations:

$A + B = C$ (1)

$A + B = 100$ (2)

Protein balance:

$0.3943A + 0.086B = 0.16\,C$ (3)

$0.3943A + 0.086B = 0.16\,(100)$ (4)

From equation (2), $A = 100 – B$ (5)

Substitute equation (5) into (4)

$0.3943\,(100-B) + 0.086B = 0.16\,(100)$

$39.43 - 0.3943B + 0.086B = 16$

$-\,0.3083B = 16 – 39.43$

$-\,0.3083B = -\,23.43$

$B = 76.00$ (i.e., amount of FARO 44 in the mixture)

From equation (2) substitute in the value of B

$A + 76.00 = 100$

$A = 100 – 76.00$

$A = 24.00$ (i.e., amount of soybean in the mixture).

Proximate analysis

The moisture content of the rice plus soybean-based complementary food was estimated gravimetrically by the AOAC method (Laboratory oven, Model DHG-9023A, Medifield Equipment & Scientific England, England). (AOAC, 1990; Nielsen, 2002). The ash content of the rice plus soybean-based formulated products was determined by dry ashing using a muffle furnace (Muffle furnace, Vecstar Ltd., Model ECF3, Chester field U.K.) at the temperature of 550 ^{o}C as described by Nielsen (2002). The fat content of the formulated food product was determined using the Soxhlet extraction method as described by Nielsen (2002). The dietary fibre of the food sample was determined by digesting soluble components of the food. The soluble and the insoluble components were separated. The final loss in weight after drying and ashing the insoluble component was noted and the fibre content of rice plus soybean-based complementary food was calculated (AOAC, 1990; Nielsen, 2002). The protein was determined using the micro-Kjeldahl procedure. A conversion factor of 6.25 (100/16 = 6.25) was used for calculating the protein contents (Egan *et al*., 1988; AOAC, 1990; Nielsen, 2002). The available percentage of carbohydrates in the food material was determined by difference i.e. {100% - % (moisture + protein + ash + fibre + fat)}. Also, the total energy value of the rice and soybean in test materials and formulated products were determined using the physiological fuel value (Atwater factor) of 17 kJ, 17 kJ and 37 kJ per gram of carbohydrates, proteins and fats, respectively, as reported by Onwuka (2005) and was calculated as kJ per 100 g of food.

Statistical Analysis

Data obtained were subjected to analysis of variance (one way ANOVA) using IBM SPSS statistics version 22 and mean values were separated by Duncan's Multiple Range Test (DMRT) at a 5% significant level (Duncan, 1955).

RESULTS AND DISCUSION

Proximate composition

Table 2 and 3 show the proximate composition of flours of the raw materials and the formulated products, respectively. The protein contents ranged from 8.44 (MNFR) to 39.43 g/100 g S, fat ranged from 1.44 (NMNFR) to 10.92 g/100 g S, ash ranged from 0.74 (MNFR) to 4.18 g/100 g S, crude fibre ranged from 0.95 (MFR) to 6.65 g/100 g S, moisture ranged from 3.26 (NMFR) to 8.49 g/100 g NMNFR, carbohydrate ranged from 34.67 (S) to 84.08 g/100 g NMFR and energy value ranged from 1543.38 (NMNFR) to 1663.79 kJ S. While among the rice products: MFR, MNFR, NMNFR, NMNFR, NMNFR, NMFR and NMFR contain the highest values of protein, fat, ash, crude fibre, moisture, carbohydrate and energy value respectively. The effect of malting and fermentation varied significantly with the proximate composition of malted and/or fermented rice. Hence, protein, fat, carbohydrate and energy values were increased, while ash, crude fibre and moisture contents decreased. Similarly, the proximate composition of the formulated rice products (Table 3) varied significantly ($p < 0.05$) except protein. The NMFRS, MNFRS, NMNFRS, NMNFRS, NMNFRS, NMFRS and NMFRS contain the highest protein, fat, ash, crude fibre, moisture, carbohydrate and energy value respectively. The addition of soybean flour to all rice products significantly improved their proximate composition (Tables 2 and 3). This was observed in their average total protein (8.80 to 15.99 g/100 g), fat (1.75 to 3.90 g/100 g), ash (0.84 to 1.60 g/100 g) and crude fibre (1.11 to 2.41 g/100 g) increased upon complementing rice with soybean flour, while the moisture (6.07 to 5.61 g/100 g) and carbohydrate (81.44 to 70.53 g/100 g) decreased.

Table 2: Effects of Malting and Fermentation on Proximate Composition of FARO 44 Rice Cultivar and Soybean Flour

	Material					
Nutrient (g/100 g)	NMNFR	MNFR	NMFR	MFR	S	LSD
Protein	8.51^{c} ± 0.09	8.44^{c} ± 0.17	8.94^{bc} ± 0.51	9.40^{b} ± 0.34	39.43^{a} ± 0.70	0.9
Fat	1.44^{c} ± 0.05	1.90^{b} ± 0.15	1.87^{b} ± 0.13	1.88^{b} ± 0.02	10.92^{a} ± 0.47	0.5
Ash	0.95^{b} ± 0.07	0.74^{c} ± 0.12	0.86^{bc} ± 0.05	0.81^{bc} ± 0.03	4.18^{a} ± 0.21	0.3
Crude fibre	1.46^{b} ± 0.12	1.05^{b} ± 0.03	0.99^{b} ± 0.02	0.95^{b} ± 0.04	6.65^{a} ± 0.85	0.8
Moisture	8.49^{a} ± 0.35	8.12^{a} ± 0.34	3.26^{b} ± 0.43	3.74^{b} ± 0.43	4.15^{b} ± 1.33	1.5
Carbohydrate	79.14^{c} ± 0.44	79.76^{c} ± 0.15	84.08^{a} ± 0.75	83.23^{b} ± 0.16	34.67^{d} ± 0.89	1.2
Energy value (kJ)	1543.38^{d} ± 6.33	1569.61^{c} ± 9.75	1650.62^{ab} ± 9.07	1644.05^{b} ± 7.01	1663.79^{a} ± 14.05	21.1

Each result is mean ± SD of quadruplicate determinations. Values with common superscripts along each raw are not significantly (p > 0.05) different. LSD = least significant difference.

NMNFR = Non-Malted - Non Fermented Rice, MNFR = Malted - Non Fermented Rice, NMFR =Non Malted – Fermented Rice, MFR = Malted – Fermented Rice, S = Soybean.

Table 3: Proximate Composition of Malted and/or Fermented Rice plus Soybean based Complementary Foods

	FARO 44 Rice + Soybean Product					
Nutrient (g/100 g)	NMNFRS	MNFRS	NMFRS	MFRS	LSD	*Recommendation (g/100 g)
Protein	15.96^{a} ± 0.19	15.99^{a} ± 0.26	16.0^{a} ± 0.33	15.94^{a} ± 0.19	0.5	8 - 16.5
Fat	3.74^{c} ± 0.12	4.10^{a} ± 0.12	3.97^{ab} ± 0.09	3.86^{bc} ± 0.11	0.7	9 – 10
Ash	1.71^{a} ± 0.07	1.58^{b} ± 0.07	1.63^{ab} ± 0.08	1.55^{b} ± 0.05	0.2	
Crude fibre	2.73^{a} ± 0.24	2.42^{ab} ± 0.20	2.30^{b} ± 0.21	2.20^{b} ± 0.16	0.4	< 5
Moisture	7.50^{a} ± 0.08	7.16^{a} ± 0.57	3.46^{b} ± 0.63	3.83^{b} ± 0.16	0.9	
Carbohydrate	68.37^{b} ± 0.35	68.76^{b} ± 0.24	72.64^{a} ± 0.69	72.63^{a} ± 0.24	0.9	60 – 75
Energy value (kJ)	1571.94^{c} ± 7.73	1592.32^{b} ± 7.47	1653.63^{a} ± 7.97	1648.47^{a} ± 7.37	16.0	1674 – 1841

Each result is mean ± SD of quadruplicate determinations. Values with common superscripts along each raw are not significantly (p > 0.05) different. LSD = least significant difference.

NMNFRS = Non-Malted - Non Fermented Rice + Soybean flour, MNFRS = Malted - Non Fermented + Soybean flour, NMFRS =Non Malted – Fermented Rice + Soybean flour, MFRS = Malted – Fermented Rice + Soybean flour.

*Recommendation (g/100 g), World Food Programme (2021)

Effects of Processing on Proximate Composition

All food products require analysis as part of a quality management program throughout the development process (including raw ingredients), through production, and after a product is in the market. To meet consumers' choices such as a wider variety of products that are of high quality (nutritious) and can offer a good value such as acceptability, safety and health benefits (Nielsen, 2010).

Protein is one of the four major classes of biomolecules that is very important in this current study. It is important because the cost of certain commodities may be based on the protein content, functional property, biological activity and amino acid composition (Gibney *et al.*, 2009; Nielsen, 2010). Protein in rice is often considered essential which influences the nutritional quality of rice. Rice protein content is up to 8% of the grain which is low but of high nutritional value (Verma, and Srivastav, 2017). These rice products obtained from this current study can be considered superior in terms of protein quantity (8.44 to 9.40 g/ 100g). Though reports from diverse literature sources have already reported that rice protein is superior in terms of quality. It is superior because of its unique composition of amino acids and has a special benefit because eight of the essential amino acids are found (Verma, and Srivastav, 2017; Chaudhari *et al.*, 2018; Mugalavai *et al.*, 2021). Verma and Srivastav (2017) carried out a comparative study between aromatic and non-aromatic Indian rice, some of the aromatic rice corresponds to this study in terms of their protein, while the non-aromatic rice contains very low levels of protein (6.87%). Other studies on different types of rice such as brown or white milled rice also revealed very low levels of protein in rice (Chaudhari *et al*., 2018; Upadhyay and Karn, 2018; Mugalavai *et al*., 2021) contrary to this study. Nutritional composition analysis of improved and released rice varieties in Ethiopia reported comparable protein contents (8.41 to 11.77%). However, some varieties were observed to be much higher (Cherie and Dagnaw, 2019). In a similar study, proximate, malting characteristics and grain quality properties of some Nigerian rice of different varieties by Osuji *et al.* (2019) increased the protein content of unmalted varieties of rice cultivars (6.18 to 8.91%) to malted rice (6.99 to 9.39) which also corresponds with this study. In addition, the study by Fosido *et al.* (2020) on the effects of fermentation and malt addition on the physicochemical properties of cereal-based complementary foods in Ethiopia also increased protein content and this finding also corresponds to this current study.

Appropriate levels of protein content in foods are important for solving protein-energy malnutrition, especially in developing countries where substantial staple foods are mostly cereals and tubers. World Food Programme (2021) recently recommended a protein content level of 8% as the minimum limit, 16% as the target and 16.5% as the maximum limit for infant complementary foods. It was observed that all the formulated complementary foods in this study met the World Food Programme (2021) target appropriately. A similar study by Chinelo *et al.* (2017) on the evaluation of complementary foods from blends of roasted rice and soybean flour recorded both low and high levels of protein. A similar study by Mariam (2005) and Obasi *et al.* (2018) still showed high levels of protein than the recommended standards. However, the study by Pobee *et al.* (2017b) moderately corresponds with the protein values obtained. Similarly, the study by Asma *et al.* (2006) met the requirements of World Food Programme (2021) and other values of protein in their results correspond with this study. However, in their findings, some formulations had high levels of protein.

Fat (lipids) which contributes to consumers' satiety, constitute one of the principal structural components of foods that supply a high amount of energy to the body. They are a group of substances that, in general, are soluble in ether, chloroform, or other organic solvents but are sparingly soluble in water (Nielsen, 2010). Fat in rice is a good source of unsaturated fatty acids which influences the taste of rice especially cooked rice because rice with high fat content tends to be tastier and have less starch (Verma and Srivastav, 2017). Fat content found in this current study was of comparative levels reported by Verma and Srivastav (2017); Upadhyay and Karn (2018) as well as Cherie and Dagnaw (2019). However, much less in values compared to the brown rice reported by Chaudhari *et al*. (2018); Upadhyay and Karn (2018) and Mugalavai *et al*. (2021). This shows higher levels of fat can be obtained from brown rice instead of white milled rice if need be. During this study, it was observed fat increased upon malting and fermentation, possibly occurring as a result of an increase in flour surface area (due to the breakdown of larger molecules) enabling the rate of fat extraction by the solvent (Nielsen, 2010). A similar trend was also reported by Forsido *et al.* (2020) but findings by Forido *et al.* (2020) indicated fat decrease during fermentation. Osuji *et al.* (2019) also reported a decrease in fat during the malting of rice grain from unmalted (5.37 to 2.90%) to malted rice (0.97 to 1.94%). It is also possible that a long period of malting or fermentation may result in significant lipid oxidation leading to a reduction in the fat content of a food material (Ihekoronye and Ngoddy, 1985; Martinus and Boekel, 2008).
Fat is also important for assessing whether the food meets the standard of identity, manufacturing specifications, products of desirable quality, functionality, and nutritional labelling (Nielsen, 2010; Devis and Khatar, 2016). Irrespective of the source, fat is the most concentrated form of dietary energy and provides 9 calories of (37.8 kJ/g) energy per gram

(Gibney *et al*., 2009.) For fat contents of complementary foods, World Food Programme (2021) recommended 9% as the minimum limit and 10% as the target. However, the fat content of all the formulations of rice and soybean-based complementary food in this study was observed to be lower than the recommended range. However, it was observed that the amount does not matter much as it can still supply dietary energy for body function. Chinelo *et al.* (2017) and Pobee *et al.* (2017) reported lower levels of fat in some formulations which are in agreement with this study, but others are higher than the recommended levels. Also, a similar study by Mariam (2005) and Meite *et al.* (2016) observed much higher levels of fat than the target range recommended by World Food Programme (2021). The study of Asma *et al.* (2006) and Obasi *et al.* (2017) on complementary foods found levels of fat which corresponds with this study. It seems researchers around the world found it difficult to meet the target requirement of fat limits in complementary foods. Others such as protein, dietary fibre, moisture, energy value etc. were often observed within the range of standard requirements.

Another essential food material is ash. Ash refers to the inorganic residue remaining after either ignition or complete oxidation of organic matter in a foodstuff. It represents the total mineral contents in food. This means the ash content of food is important for evaluating the mineral richness or deficiency of food. This entails the higher the ash contents of food the higher its mineral contents (Gibney *et al*., 2009; Nielsen, 2010). The study conducted by Verma and Srivastav (2017), reported compiled data from 22 scientific papers about the ash content of rice submitted to conventional milling, reviled ash contents vary from 0.3 to 0.8%. Further comparisons were made from literature data on the total ash content, and in their findings, values around 0.5% were the most common. However, recent studies conducted by Chaudhari *et al*. (2018); Upadhyay and Karn (2018); Cherie and Dagnaw (2019) as well and Mugalavai *et al*. (2021) showed higher levels of ash in rice, especially in brown rice. Some of these findings also slightly correspond with this current study especially Mugalavai *et al*. (2021). The effect of malting and fermentation of the rice caused a slight decrease in their ash content as observed, which agreed slightly with Osuji *et al.* (2019) finding. Similarly, Forsido *et al.* (2020) reported an increase or decrease (slightly) of ash upon fermentation.

Traditional enrichment of rice with soybean by Meite *et al.* (2016) corresponds to this study in terms of their ash contents. Research conducted by Mariam (2005) on the nutritive value of three potential complementary foods based on cereals and legumes found levels of ash comparable with this study. Pobee *et al.* (2017) and Asma *et al*. (2006) in their studies found similar levels of ash contents. But Chinelo *et al.* (2017) and Obasi *et al.* (2018) reported much higher levels than in this study.

Fibre is also one of the food constituents that is getting much attention among researchers, food manufacturers and consumers. American Association of Cereal Chemists (now AACC International) defined dietary fibre as the edible parts of plants or analogous carbohydrates (cellulose, hemicelluloses, lignin, and other non-starch plant polysaccharides such as pectin) that are resistant to digestion and absorption in the human intestine, also with complete or partial fermentation in the large intestine. As dietary fibre, they regulate normal bowel function, reduce the postprandial hyperglycaemic response, and may lower serum cholesterol, among other effects (Gibney *et al*., 2009; Nielsen, 2010). Reports of fibre in rice vary. Chaudhari *et al*. (2018); Upadhyay and Karn (2018); Cherie and Dagnaw (2019) as well as Mugalavai *et al*. (2021) reported much higher levels of rice fibre (1.3 to 4%) compared to this current study. Also, Verma and Srivastav (2017) conducted a study on proximate composition, mineral content and fatty acids analyses of aromatic and non-aromatic Indian rice, indicating a slightly lower amount of fibre than in this study. Verma and Srivastav (2017) further reported the standard fibre content for well-milled rice as 0.5 to 1.0% and this slightly corresponds with this study. Similar reports indicated fibre contents did not vary during the malting of rice (Osuji *et al*., 2019). However, a different study showed fibre contents of rice reduced significantly during fermentation (Forsido *et al*., 2020) which agreed with this study. Fibre which contributes to the dietary bulk of food play an important role in the body of infants, children or adults. Dietary fibre promotes beneficial physiological effects, such as laxation, and/or blood cholesterol or glucose attenuation and peristalsis (Gibney *et al*., 2009; Nielsen, 2010). Individual levels of fibre requirement in foods differ. High level of fibre in infants' foods may cause stomach ache. The recommended limit of fibre in complementary foods is less than 5% (Codex Alimentarius Commission, 1991; FAO, 1995b; European Commission, 2003; Nestle Nutrition Institute, 2005; Codex Alimentarius Commission, 2015). Chinelo *et al.* (2017) and Pobee *et al.* (2017) reported a slightly lesser amount of fibre in complementary foods than in this study. However, the study by Mariam (2005) and Meite *et al*. (2016) on complementary foods revealed similar levels of fibre as in this study. But Asma *et al.* (2006) reported fibre contents much less and Obasi *et al.* (2017) found much higher levels of fibre as compared with this study. Nevertheless, their findings were within the range of standard limits.

Another important quality parameter of food is moisture. Moisture is being used as a quality factor for preservation, standard, convenience in packaging and shipping, compositional standards, and computations of the nutritional value of foods (Nielsen, 2010). Moisture content invariably affects the quality and palatability of rice grains which plays a significant role in determining the shelf life (Verma and Srivastav, 2017). In this study, it was observed that all flours of rice or soybean were found to possess desired moisture levels below the needed acceptable limit (12%) for long-term storage of rice (Verma and Srivastav, 2017). Such moisture contents if attended can prolong the storage time of rice or rice products much longer than expected (and that is what is required) which is an advantage for both processor and consumer. Studies conducted by Chaudhari *et al.* (2018); Upadhyay and Karn (2018); Cherie and Dagnaw (2019) and Mugalavai *et al.* (2021) on rice indicated much higher levels of moisture (8.9 to 14%) compared to this study. This is also an achievement made in this study. In a similar study, which carried malting or fermentation, their effect resulted in a reduction in moisture contents (Osuji *et al*.,2019; Forsido *et al*., 2020) and this agreed with current findings. However, their findings on moisture reduction were not much as compared with this study.

The moisture content requirement of certain foods may differ from one particular food to the other. For example, prepared conventional cereals (4 - 8% moisture), liquid corn sweetener (≤ 20% moisture), glucose syrup (≤ 30% moisture), cheddar cheese (≤ 39% moisture), cereal flour or its blends (≤ 15% moisture), complementary foods (≤ 10% moisture) as reported by Codex Alimentarius Commission (1991); FAO (1995); European Commission (2003); Nestle Nutrition Institute (2005); Nielsen (2010); Codex Alimentarius Commission (2015). Regulatory bodies recommended the moisture content of complementary food mostly less than 10% (Codex Alimentarius Commission, 1991; European Commission, 2003; Nestle Nutrition Institute, 2005; Nielsen, 2010; Codex Alimentarius Commission, 2015). However, moisture content alone is not a good predictor for food spoilage. But it is known that low moisture level of food could entails long keeping time, since it often corresponds to low water activity. It was observed that all the moisture content (3.46 to 7.50 g) of rice and soybean-based complementary foods was within the recommended range. It was reported that such food will have a good shelf life unless there is significant moisture absorption from around the food material, which will, in turn, expose the food to spoilage, rendering it unfit for human consumption (Verma and Srivastav 2017). In many related studies on rice and soybean complementary foods, the moisture content of the food material often is found within the recommended range of the regulatory bodies. Chinelo *et al*. (2017) evaluated the quality parameters of complementary food from blends of roasted rice and soybean flours within the moisture content of 6.98 to 7.87% which corresponds to the findings of this study. Another study by Mariam (2005) on the value of three potential complementary foods based on cereals and legumes obtained very low moisture content (3.70 to 5.15%) similar to the moisture content (3.46 to 4.15%) of those formulated foods in this study. Obasi *et al*. (2018) similarly reported a low moisture content of 4.43% from formulated blends of sprouted paddy rice, African yam beans and pawpaw fruits. The development of weaning food by Asma *et al.* (2006) also has a corresponding low moisture content. A similar study on complementary foods from rice and six other Ghanaian food ingredients had a moisture content of 6.7 to 9.70 (Pobee *et al*., 2017) which slightly corresponds to the moisture contents of the formulated - non-fermented foods.

Carbohydrate is an important constituent of foods and one of the four major classes of biomolecules. It is regarded as soluble starch (i.e., starch polymers or amylose and amylopectin molecules) and the only polysaccharides that humans can digest, and use as a source of calories and carbon (Nielsen, 2010). It is also important as other major sources of energy. It contributes to desirable textures from crispness to smooth, and soft gels as well as functional properties such as bulk density, viscosity, stability to emulsions and foams, water-holding capacity, freeze-thaw stability, browning and also flavours (Gibney *et al*., 2009; Nielsen, 2010). Rice carbohydrates are always considered superior in quality. Reports by Upadhyay and Karn (2018) showed values of carbohydrate contents in rice, slightly in agreement with this study. Other studies conducted by Chaudhari *et al*. (2018); Cherie and Dagnaw (2019) and Mugalavai *et al*. (2021) indicated lower levels of carbohydrate content as compared to these studies. A similar study on the malting of rice by Osuji *et al*. (2019) showed an increased carbohydrate in unmalted rice (73.77 to 80.28) to malted rice (79.78 to 84.84%). But study by Forsido *et al*. (2020) showed a decrease in the carbohydrates of oats and an increase in the carbohydrates of barley and teff during the fermentation of their flours. The increase in carbohydrate of flours during malting and fermentation studies reported by these researchers slightly corresponds with this study.

It was reported by Gibney *et al*. (2009) and Nielsen (2010) that no polysaccharide other than starch is digested in the human small intestine. Digestible carbohydrates, which are converted into monosaccharides, are absorbed and provide metabolic energy (Gibney *et al*., 2009; Nielsen, 2010). Worldwide, carbohydrates account for more than 70% of the caloric value of the human diet. It is recommended that all persons should limit calories from fat to not more than 30% and that most of them should come from carbohydrate calories (Gibney *et al*., 2009; Nielsen, 2010). Carbohydrates provide satiety and as a body for housing other nutrients (Gibney *et al*., 2009; Nielsen, 2010). It contributes a greater part of calories or energy to the body. It is required in foods to balance the chemical constituents of protein in the body (Nielsen, 2010). Obasi *et al*. (2018) and Asma *et al*. (2006) in their study found carbohydrate contents with similar results to the current study. However, Chinelo *et al*. (2017) found much lower and also higher levels of carbohydrates. The study by Pobee *et al*. (2017) revealed slightly lower and Mariam (2005) revealed much lower carbohydrate contents as well as Meite *et al*. (2016) reported much lower carbohydrate contents in three formulations out of four, except in one formulation which agreed with this study.

Energy value or intake is also a function of fat, protein and carbohydrate and is defined as the caloric or energy content of food as provided by the major sources of dietary energy (carbohydrate provide 16.8 kJ/g, protein provide 16.8 kJ/g, whereas fat is the most energy dense provide 37.8 kJ/g, and alcohol provide 29.4 kJ/g). A "calorie," which is the standard for measurement of the energy value of substances and to express the body's energy requirement, is the amount of heat required to raise the temperature of 1 g of water by 1◦C (1 calorie = 4.184 joules). The unit used in nutritional work is "Calorie" or "kilo-calorie" (kcal), which equals 1000 calories (Gibney *et al*., 2009; Nielsen, 2010). These units of energy are being used for assessing or evaluating food quality. Both are still used, but the kJ is recommended to replace kilo-calorie. Verma and Srivastav (2017) and Cherie and Dagnaw (2019) reported a lower energy value of rice compared to this study. On the other hand, Chaudhari *et al*. (2018) reported a slightly comparable value of energy from rice. Reports from Forsido *et al*. (2020) showed a slight energy decrease in oats, barley and teff during the fermentation of flours.
The energy value of complementary foods recommended by World Food Programme (2021) are 400, 420 and 440 (kcal) for minimum, target, and maximum limits respectively. This study was observed to be slightly lower in energy value compared to the standard recommended range required for complementary foods. low levels of energy values were observed to be the result of low levels of fat content in the formulated food products. A study conducted by Obasi *et al.* (2018) indicated energy values comparable with this study. However, Asma *et al*. (2006) appropriate range of energy value. While Mariam (2005) reported much higher energy values than it was recommended. However, the study by Pobee *et al.* (2017) indicated comparable energy values with some being within the recommended range reported by World Food Programme (2021).

It was observed that malting and fermentation of rice have an added advantage over non-malted rice for producers and consumers (Kabeir *et al*., 2004). The slight increase in protein, fat, carbohydrate and energy is an added advantage for the formulation of food products. Reduction in moisture and fibre as observed are also an added advantage for good keeping quality and good characteristics qualities of complementary foods, respectively. However, the decrease in ash as a result of the effect of malting and fermentation is a disadvantage because it indicates the loss of essential mineral elements in processed foods as earlier reported.

CONCLUSIONS

Malting and/or fermentation slightly increased protein (except malting alone), fat, carbohydrate and energy values while ash, crude fibre and moisture contents were decreased. The proximate composition of the malted and/or fermented rice are slightly inadequate to meet infants' requirements. However, addition of soybean to rice flours improves the proximate composition of formulated food products which are within the recommended level except in terms of fat. Acceptable products were formulated from malted and/or fermented rice plus soybean flour with the potentials of application as complementary foods for addressing protein energy malnutrition, especially in children.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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