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Effects of *Raphia sudanica* Mesocarp and Arrowroot (*Tacca involucrata*) Flour Incorporation on the Chemical Composition of Sorghum Composite Spaghetti

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Abstract

Obesity and food allergy (celiac disease) are serious public health problems, which should be addressed through encouraging the consumption of foods with high amount of low digestible carbohydrates and gluten free. Obesity arises through an imbalance between energy intake and energy expenditure, so it is important for products to have a balanced nutritional composition. Spaghetti is low in sodium, iron, fat, lysine, threonine and vitamins but a rich source of complex carbohydrates. The study evaluated the mineral elements, phytochemical, amino and fatty acids composition and sensory properties of sorghum/*Raphia sudanica*/*Tacca involucrata* spaghetti. The iron, zinc, potassium and calcium contents of the composite spaghetti samples increased with every 5% addition of *Raphiasudanica* mesocarp flour while the magnesium and sodium contents decreased. The total flavonoids, polyphenols, amino and fatty acids contents were also elevated with every 5% addition of *Raphia sudanica* mesocarp flour. Spaghetti sample 200:50:100 g was generally the most accepted by consumers. *Raphia sudanica* mesocarp flour is a rich source of mineral elements, polyphenols, amino and fatty acids. Its use as a food fortificant may improve the nutritional and health status of man.

Keywords

Sorghum, Arrowroot, *Raphia sudanica* Mesocarp, Phytochemicals, Amino and Fatty Acids

1. Introduction

Pasta is a popular convenience food worldwide, prepared from durum wheat using extrusion cooking. Pasta produced with wheat has better quality characteristics. In pasta processing, gluten is mainly responsible for the formation of structure and considered the most significant factor to pasta cooking quality [1] [2]. Researchers have used other grains or pseudo cereals to partially or fully replace durum semolina to prepare gluten free (GF) or low glycemic index pastas for special nutrition [3] [4] [5]. People with specific genetic nature suffer from celiac disease (with a prevalence of 5%) which is usually manifested as a digestive malfunction of the intestines caused by the presence of gluten [6] [7]. The only effective treatment is a life-long gluten free diet [8] [9] or exclusion of the intake of storage proteins found in wheat, rye, barley and oats from their diet [10]. The main reason for the more recent spread of different pasta types is an awareness of consumers about nutrition, with relation to good health and an overall healthy lifestyle [11] [12]. Pasta is usually considered a healthy food when fortified with fibre, and less commonly, it is associated with a high content of minerals, such as calcium. Consumers today are increasingly interested in foods with health-promoting ingredients [13] [14] and food with nutrition and/or health claims on their labels, which are designed to offer useful information to the consumer about the health benefits of a product, while current legislation protects consumers from misleading and false information [15].

The gluten free nature of sorghum makes it appropriate food for those with celiac disease or other forms of allergies or wheat intolerance [16]. Sorghum (*Sorghum bicolor* (*L.*)) is an important staple food crop in sub-Saharan Africa. Its slow digestibility, rich polyphenolic, antioxidant constituents and gluten free content have been harnessed in the production of several food products [17] [18]. Previous research has shown that minimum amount of sorghum can be used to produce noodles [19] [20] and pasta with combination of other cereals [21].

Raphia sudanica is an economically useful plant in Africa that produces palm sap which is fermented and drank as alcoholic beverage [22]. The oily mesocarp of the fruit is used in traditional medicine for its laxative and stomachic properties and as a linimat for pains. The ripe fruits are cooked and the mesocarp eaten in north-central, Nigeria. It is greatly underutilized and exploited in the food industry.

Arrowroot (*Tacca involucrata*) is a wild edible plant whose tubers contain starch which is processed into flour and used in the preparation of stiff starch porridges [23]. It is of the family Dioscoreaceae but formerly classified under the family Taccaceae [24]. Arrowroot has relatively high amounts of resistant starch which is non-digestible and therefore acts as fiber [25]. Its incorporation in spaghetti production may reduce the risks of obesity, cardiovascular diseases and diabetes, in addition being gluten free, may replace wheat in certain food applications to reduce the incidence of celiac disease (CD) or other allergic reactions to gluten [26].

The nutritional value of pasta is not very high as it is rich in starch and devoid of dietary fibre. Incorporation of high fiber material enhances the nutritional and functional quality of pasta [27]. Keeping in view the above findings of researchers, the study evaluated the mineral elements, phytochemical, amino and fatty acids composition and sensory properties of sorghum/*Raphia sudanica*/*Tacca involucrata* spaghetti.

2. Materials and Methods

2.1. Sources of Material

Sorghum grains and Arrowroot (*Tacca involucrata*) flour were purchased from Makurdi while fresh *Raphia sudanica* fruits were purchased from Kastina-Ala all located in Benue State, Nigeria.

2.2. Sorghum Flour Production

Sorghum grains were cleaned to remove extraneous plant parts and stones, washed and sun dried (5 hr). This was followed by dry milling (hammer mill) and sieving (0.2 mm mesh screen). The flour was packaged in air tight plastic container until needed.

2.3. Production of *Raphia sudanica* Flour

Fresh *Raphia sudanica* fruits were peeled and sun dried (72 hr) to constant weight. The dried fruits mesocarp were separated from the nuts, dry milled (hammer mill), sieved (0.2 mm mesh screen) and packaged (air tight plastic container) until needed.

2.4. Blends Formulation

Sorghum and *Raphia sudanica* mesocarp flours were blended on percentage basis as shown in **Table 1**. The quantity of Arrowroot flour (used as a binding and gelling agent) was kept constant while that of sorghum and *Raphia sudanica* mesocarp flour were varied by 5%.

2.5. Production of Sorghum/*Raphia sudanica/Tacca involucrata* Composite Spaghetti

Three hundred and fifty grams of sorghum/*Raphia sudanica/Tacca involucrata* composite flour was stirred into 220 ml warm water (85˚C) in an aluminum pot with application of heat on a gas cooker for five minutes, to form homogeneous dough. Thereafter, the dough was kneaded in a stainless bowl until soft and smooth, extruded using Marcato Atlas pasta machine (model 190, Italy) through 12 mm size screw hole. The extruded spaghetti was dried at ambient temperature.

2.6. Mineral Elements Determination

The iron, zinc, magnesium, calcium and manganese contents of the composite spaghetti were determined using atomic absorption spectrophotometry (Buck 210) while sodium and potassium contents were determined using flame

Table 1. Blend formulation of sorghum/*Raphia sudanica*/*Tacca involucrata* composite flour for spaghetti production.

Sample	SF (g) %	RF (g) %	AF (g)
AGE1	250 (100)	-	100
AGE2	237.5 (95)	12.5(5)	100
AGE3	225 (90)	25 (10)	100
AGE4	212.5 (85)	37.5 (15)	100
AGE5	200 (80)	50 (20)	100

Key: SF = Sorghum flour, RF = *Raphia sudanica* mesocarp flour, AF = Arrowroot flour; AGE1 = 250:0:100 g Sorghum/Arrow root composite spaghetti; AGE2 = 237.5:12.5:100 g Sorghum/Arrow root/Raphia composite spaghetti; AGE3 = 225:25:100 g Sorghum/Arrow root/Raphia composite spaghetti; AGE4 = 212.5:37.5:100 g Sorghum/Arrow root/Raphia composite spaghetti; AGE5 = 200:50:100 g Sorghum/Arrow root/Raphia composite spaghetti.

photometry (Jenway ME882, via air acetylene flame integrated mode) according to AOAC [28] method.

2.7. Phytochemical Determination

Thirty milligrams (30 mg) each of the composite spaghetti samples were separately weighed and dissolved with hexane in a 1.0 ml vials. Ten milliliters (10 ml) each of the prepared samples were then injected into a Buck scientific (USA) BLC10/11 High Performance Liquid Chromatography (HPLC) system with a fluorescence detector (excitation at 295 nm and emission at 325 nm) and an analytical silica column (25 cm × 4.6 mm ID, stainless steel, 5 µm) was used to analyze phytochemicals. The mobile phase used was hexane: tetrahydrofuran: Isopropanol (1000:60:4/v/v/v) at a flow rate of 1.0 ml/min. Standard samples were also prepared using similar methods. Concentration of phytochemicals in the samples was calibrated using authentic standards [29]. The concentration of phytochemicals in the samples was calculated thus:

$$\text{conc. of phytochem.}(\text{ppm}) = \frac{\text{area of sample} \times \text{conc. of std}(\text{ppm}) \times \text{vol. of hexane}(\text{ml})}{\text{area of std} \times \text{wt. of sample}}$$

2.8. Fatty Acids Determination

The lipids were extracted from samples by Soxhlet extractor using hexane as a solvent. Fatty acids were transformed into methyl ester according to the ISO procedure [29]. The fatty acid methyl esters (FAMEs) were extracted with petroleum ether and were analyzed by high pressure liquid chromatography (HPLC) (Buck scientific BLC 10/11 USA) equipped with a flame ionization detector and integrator. The mobile phase is (59:41) acetonitrile: 2-propanol and the column (Prevail C-18.5 u, 150 × 4.6 mm) flow rate was 1 mL/min. The oven temperature was maintained at 210˚C for 45 min. The fatty acids were identified by comparing their retention times with those of standards [30].

2.9. Amino Acids Determination

The defatted flour samples from fatty acid determination were utilized to estimate amino acids. The sample (30 mg) was hydrolyzed with 6N HCI at 110˚C for 24 h [28]. Amino acid analysis was performed on reverse phase high pressure liquid chromatography (HPLC) (Buck scientific BLC 10/11 USA). The post column samples were derivatized with ophthaldialdehyde and data were integrated using peak simple chromatography data system (Buck SCI chromatopac data processor). Tryptophan was determined spectrophotometrically after alkaline hydrolysis of the samples [31].

2.10. Sensory Evaluation

Sensory evaluation of the cooked spaghetti was conducted using 7 point hedonic scale (1 = dislike very much and 7 = like very much). Twenty (20) panelists evaluated the spaghetti samples for appearance, colour, taste, flavor, texture and overall acceptability [32].

2.11. Cooking Procedure

Pasta samples were dried to constant weight at 90˚C for 2 - 3 h. One hundred and fifty grammes of dry pasta were added to 500 ml distilled boiling water free of sodium chloride and cooked for 5 minutes. The cooked pasta was drained and surface water removed by keeping over a thin muslin cloth. The cooked spaghetti samples were kept in food warmers for use in sensory analysis.

2.12. Statistical Analysis

The data obtained was subjected to Analysis of Variance (ANOVA) at 5% level of significance, using SPSS software version 25.0.

3. Results and Discussion

3.1. Mineral Elements Composition of the Composite Spaghetti

Table 2 presents the mineral elements content of sorghum/*Raphia sudanica/Tacca involucrata* composite spaghetti. The result showed that, *Raphia sudanica* mesocarp flour characterized with its high mineral contents improved the mineral contents of the composite spaghetti blends, especially at a higher replacement level. The iron contents of composite spaghetti blends were higher than 0.45 - 0.56 mg/100 g iron contained in maize/sorghum/water melon seeds composite spaghetti blends [32]. The iron contents of this study were however lower than 8.426 - 23.936 mg/100 g contained in rice/dried banana composite spaghetti but similar to those of rice/fresh banana and rice/fresh banana pre-treated with ascorbic acid composite spaghetti [33] Moisture reduction has been reported to cause concentration in nutrients profile of dehydrated products [34]. The high iron contents of this study are of health significance in promoting haemoglobin formation and transportation of oxygen in the body.

The zinc contents of the study were higher than 0.64 mg/100 g to 0.80 mg/100 g reported for wheat semolina/guava seed pasta [35]. The differences in the zinc content between the two composite spaghetti blends may be due to differences

Table 2. Mineral element content of sorghum/*Tacca involucrata*/*Raphia sudanica* composite spaghetti (mg/100 g).

Samples	Micro-minerals		Macro-minerals			
	Fe	Zn	Mg	K	Na	Ca
AGE1	8.66 ± 0.01^{f}	7.26 ± 0.01^{e}	143.54 ± 0.02^{a}	685.32 ± 0.01^{e}	71.25 ± 0.01^{a}	132.54 ± 0.02^{f}
AGE2	9.11 ± 0.01^{e}	7.96 ± 0.01^{e}	132.08 ± 0.01^{b}	695.08 ± 0.01^{e}	65.35 ± 0.01^{b}	145.32 ± 0.01^{e}
AGE3	11.44 ± 0.02^{d}	10.43 ± 0.01^{d}	122.75 ± 0.01^{c}	716.34 ± 0.02^{d}	59.15 ± 0.01^{c}	152.87 ± 0.02^{d}
AGE4	13.12 ± 0.01^{c}	13.62 ± 0.00^{c}	104.62 ± 0.00^{d}	844.21 ± 0.02^{c}	55.39 ± 0.01^{d}	152.35 ± 0.01^{c}
AGE5	14.24 ± 0.02^{b}	14.24 ± 0.02^{b}	89.81 ± 0.23^{e}	952.32 ± 0.01^{b}	47.64 ± 0.02^{e}	162.04 ± 0.00^{b}
AGE6	21.35 ± 0.01^{a}	23.15 ± 0.01^{a}	45.22 ± 0.01^{f}	1452.63 ± 0.01^{a}	40.15 ± 0.00^{f}	412.53 ± 0.01^{a}

Means in a row with same superscript are significantly not different at p > 0.05; AGE1: 250 g sorghum, 0 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE2: 237.5 g sorghum, 12.5 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE3: 225 g sorghum, 25 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE4: 212.5 g sorghum, 37.5 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE5: 200 g sorghum, 50 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE6: *Raphia sudanica* flour.

in iron contents of the cereals (sorghum and wheat) and fruits (raphia and guava) used in their production. It may also be due to differences in the sensitivity of analytical methods used in zinc determination and production procedures used in spaghetti production.

The magnesium content of this study were higher than 5.23 - 5.66 mg/100 g reported for maize/sorghum/water melon seeds spaghetti [32] but lower than 122.19 - 148.35 mg/100 g contained in wheat semonila/guava composite spaghetti [35]. The magnesium contents of the composite spaghetti were inversely proportional to *Raphia sudanica* mesocarp flour content. Its levels in the composite spaghetti may be used in the management of anxiety and stress and in relieving insomnia, due to its enzymatic role in releasing hormones that calm the body and induce sleep.

The potassium content of the composite spaghetti diverged from 685.32 mg/100 g (AGE1) - 952.32 mg/100 g (AGE5). The use of wheat/guava composite in spaghetti production gave similar increases in potassium contents [34] but contradicts decreases in potassium contents of maize/sorghum/water melon seeds, maize/water melon seeds and sorghum/water melon seeds spaghetti blends [32]. Five hundred (500 g) grammes of the composite spaghetti blends may provide 4700 mg recommended daily intake of potassium to 14 years old female and male. The high potassium levels may be harnessed in the management/treatment of hypertension and other cardiovascular diseases of man. Potassium has been reported to reduce tension in blood vessels and ensure proper distribution of oxygen to vital organ system [36]. It has also been reported to protect against cardiovascular diseases [37], treat hypoglycemia and kidney disorder, alleviate muscle disorders and cramps, boost brain function, manage arthritis and diabetes [38] [39].

The sodium content of the composite spaghetti blends stretched from 71.25 mg/100 g (AGE1) to 47.64 mg/100 g (AGE5), indicating that *Raphia sudanica* mesocarp flour is a poor source of sodium. The low sodium contents of the composite spaghetti could be harnessed in the management/treatment of sodium induced hypertension. High dietary sodium intake has been implicated in the etiology of hypertension, and other cardiovascular diseases [39]. The sodium contents of this study were higher than 0.24 - 0.35 mg/100 g contained in maize/sorghum/water melon seeds spaghetti [32] but lower than 650.76 - 702.74 mg/100 g contained in wheat semolina/guava seeds composite pasta [35].

The calcium content of the composite spaghetti ranged from 132.54 mg/100 g (AGE1) - 162.04 mg/100 g (AGE5). The high calcium contents of the composite spaghetti blends may be employed in the dietetic management/treatment of calcium induce osteoporosis/osteomalacia in humans. The increased calcium content of this study was in agreement with increase in calcium content of maize/sorghum/water melon composite pasta [32]. Calcium is important in boosting bone health and improving dental health. It is important in treating obesity, colon cancer, and heart and kidney disorder.

3.2. Sorghum/*Raphia sudanica*/*Tacca involucrata* Composite Spaghetti Phytochemicals [40]

The phytochemical composition of the composite spaghetti blends is presented in **Table 3**. The total flavonoids and phytosterols contents of this study were significantly elevated for every 5% increase in *Raphia sudanica* mesocarp flour, indicating it to be a good source of flavonoids (31.66 mg/100 g) and phytosterols (64.54 mg/100 g). Flavonoids help to fight against Parkinson's disease, diabetes mellitus and lower blood pressure, and risk of stroke [41]. The increases in total polyphenol contents of the study were higher than 196.95 - 227.80 mg/100 g of dried banana fortified pasta [33]. Polyphenols are important in preventing and reducing the progression of diabetes, cancer and neurodegenerative and cardiovascular diseases. They also act as prebiotic that boost health, weight management and disease prevention.

3.3. Amino Acids Composition of Composite Spaghetti Samples

The amino acid content of the composite spaghetti blends is presented in **Table 4**. The total amino acids content in the sorghum/arrowroot and sorghum/raphia sudanica mesocarp/arrowroot pasta were 67.37 mg/100 g and 68.69 - 88.26 mg/100 g of dry matter, respectively. The protein content of the composite spaghetti consisted of 10 essential and 8 non-essential amino acids with threonine, phenylalanine, tryptophan, valine, leucine and arginine representing 31.91% of essential amino acids while glutamic and aspartic acids represented 23.69% of the non-essential amino acids. The amino acids contents of the composite spaghetti increased with every 5% replacement of sorghum flour. The increment in essential amino acid contents with sorghum flour replacement was in the order of methionine < histidine < isoleucine < lysine < tryptophan < threonine < phenylalanine < valine < arginine < leucine. The non-essential amino acids increased the order of cytosine < proline < alanine < serine < glycine < tyrosine < aspartic acid < glutamic acid.

Table 3. Total flavonoids and polyphenols composition of sorghum/*Tacca involucrata/Raphia sudanica* composite spaghetti (mg/100 g).

Samples	Total Flavonoids	Polyphenols
AGE1	8.66 ± 0.01^{f}	31.54 ± 0.02^{f}
AGE2	9.05 ± 0.02^{e}	34.64 ± 0.01^{e}
AGE3	11.21 ± 0.01^{d}	38.16 ± 0.01^{d}
AGE4	12.63 ± 0.01^{c}	41.63 ± 0.01^{c}
AGE5	13.75 ± 0.01^{b}	43.23 ± 0.02^{b}
AGE6	31.66 ± 0.01^{a}	64.54 ± 0.02^{a}

Means in a row with same superscript are significantly not different at p > 0.05; AGE1: 250 g sorghum, 0 g *Raphia sudanica*, 100 g *Tacca involucrate*; AGE2: 237.5 g sorghum, 12.5 g *Raphia sudanica*, 100 g *Tacca involucrata;* AGE3: 225 g sorghum, 25 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE4: 212.5 g sorghum, 37.5 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE5: 200 g sorghum, 50 g *Raphia sudanica*, 100 g *Tacca involucrata;* AGE6: *Raphia sudanica* flour.

Table 4. Amino acid composition of sorghum/*Tacca involucrate*/*Raphia sudanica* composite spaghetti (mg/100 g).

ESSENTIAL AMINO ACIDS						
Amino acids	AGE1	AGE2	AGE3	AGE4	AGE5	AGE6
Lysine	2.03 ± 0.01^{f}	2.62 ± 0.01^{e}	2.82 ± 0.01^{d}	3.00 ± 0.00^{c}	3.16 ± 0.01^{b}	3.46 ± 0.01^{a}
Methionine	1.05 ± 0.01^{e}	1.13 ± 0.01^{d}	1.66 ± 0.01^{c}	1.94 ± 0.01^{a}	1.93 ± 0.01^{a}	1.87 ± 0.01^{b}
Threonine	2.12 ± 0.01^{f}	2.25 ± 0.00^{e}	3.52 ± 0.01^{d}	4.07 ± 0.01^{c}	4.44 ± 0.05^{b}	5.13 ± 0.01^{a}
Phenylalanine	3.68 ± 0.01^{f}	3.72 ± 0.01^{e}	3.84 ± 0.01^{d}	4.34 ± 0.01^{c}	4.76 ± 0.01^{b}	4.81 ± 0.01^{a}
Tryptophan	3.65 ± 0.01^{e}	3.53 ± 0.01^{f}	3.78 ± 0.01^{d}	4.11 ± 0.01^{c}	4.32 ± 0.01^{b}	4.38 ± 0.01^{a}
Histidine	1.79 ± 0.01^{e}	1.85 ± 0.01^{d}	1.87 ± 0.01^{d}	2.45 ± 0.00^{c}	2.67 ± 0.01^{b}	2.83 ± 0.01^{a}
Valine	3.93 ± 0.01^{e}	4.04 ± 0.02^{d}	4.01 ± 0.01^{d}	4.87 ± 0.02^{c}	5.04 ± 0.01^{b}	5.24 ± 0.01^{a}
Isoleucine	2.18 ± 0.01^{f}	2.85 ± 0.01^{c}	3.30 ± 0.00^{a}	2.56 ± 0.01^{e}	2.97 ± 0.00^{b}	2.66 ± 0.01^{d}
Leucine	6.94 ± 0.01^{f}	6.84 ± 0.01^{e}	7.34 ± 0.01^{c}	8.13 ± 0.01^{b}	8.23 ± 0.01^{a}	8.23 ± 0.01^{a}
Arginine	4.05 ± 0.00^{e}	4.23 ± 0.01^{d}	4.24 ± 0.01^{d}	4.96 ± 0.02^{c}	5.12 ± 0.01^{b}	5.60 ± 0.02^{a}
NON-ESSENTIAL AMINO ACIDS						
Serine	2.97 ± 0.01^{e}	2.96 ± 0.01^{e}	3.13 ± 0.01^{d}	3.78 ± 0.01^{c}	4.01 ± 0.01^{b}	4.34 ± 0.01^{a}
Cytosine	0.62 ± 0.01^{e}	0.65 ± 0.01^{e}	0.70 ± 0.01^{d}	0.97 ± 0.01^{c}	1.17 ± 0.01^{b}	1.70 ± 0.02^{a}
Tyrosine	4.46 ± 0.01^{b}	4.14 ± 0.01^{b}	4.62 ± 0.01^{b}	6.10 ± 0.01^{a}	6.03 ± 0.01^{a}	6.53 ± 0.01^{a}
Alanine	2.57 ± 0.01^{e}	2.46 ± 0.01^{f}	2.72 ± 0.01^{d}	3.71 ± 0.01^{c}	3.82 ± 0.01^{b}	3.93 ± 0.01^{a}
Aspartic acid	9.34 ± 0.01^{e}	9.32 ± 0.01^{e}	9.52 ± 0.01^{c}	10.14 ± 0.01^{c}	10.46 ± 0.01^{b}	11.13 ± 0.01^{a}
Glutamic acid	10.99 ± 0.01^{f}	11.06 ± 0.01^{e}	11.14 ± 0.00^{d}	12.47 ± 0.01^{c}	13.23 ± 0.01^{b}	14.26 ± 0.01^{a}
Glycine	3.25 ± 0.01^{e}	3.27 ± 0.01^{e}	3.43 ± 0.01^{d}	4.44 ± 0.01^{c}	4.62 ± 0.01^{b}	4.82 ± 0.01^{a}
Proline	1.75 ± 0.00^{e}	1.77 ± 0.01^{e}	1.83 ± 0.01^{d}	2.28 ± 0.01^{c}	2.62 ± 0.02^{b}	2.91 ± 0.01^{a}

Means in a row with same superscript are significantly not different at p > 0.05; AGE1: 250 g sorghum, 0 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE2: 237.5 g sorghum, 12.5 g *Raphia sudanica*, 100 g *Tacca involucrata*; AGE3: 225 g sorghum, 25 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE4: 212.5 g sorghum, 37.5 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE5: 200 g sorghum, 50 g *Raphia sudanica*, 100 g *Tacca involucrata;* AGE6: *Raphia sudanica* flour.

The replacement of sorghum flour with Raphia sudanica mesocarp flour in sorghum pasta production significantly increased lysine content, from 2.03 mg/100 g (control) to 2.62 - 3.16 mg/100 g of dry matter (dm), and threonine from 2.12 mg/100 g (control) to 2.25 - 4.44 mg/100 g of dm. This was in conformity with Shogren *et al.* [42] who observed that high-lysine content spaghetti can be obtained by adding up to 35% soy flour without an adverse effect on the flavor and texture. Raphia sudanica mesocarp flour is rich in glutamic acid and proline, which are the functional amino acids in dough formation, as they provide sulfhydryl groups for the disulphide bond formation that links these glutenin protein macromolecules. The branched-chain amino acids (BCAAs) leucine, isoleucine and valine are indispensable amino acids. Apart from being building blocks of proteins, they also function as physiological stimulants (especially leucine) for protein synthesis and can promote anabolic effects on protein metabolism by increasing the rate of protein synthesis and decreasing the rate of protein degradation [43]. BCAAs can function as pharmacological nutrients for patients with decompensated liver cirrhosis. However, the effects of BCAAs at the early stages of chronic liver disease are not clear [44]. Consumption of high amounts of BCAAs is usually associated with consumption of food supplements, rather than conventional food, and especially pasta. Nevertheless, the nitrogen balance should also be taken in consideration, at the same level that is usually included in food supplements. Data from previous studies [45] [46] have suggested that oral BCAA supplementation can be useful to improve protein catabolism and lipolysis in cirrhotic patients. Similar findings were reported when Kuwahata *et al.*, [46] studied BCAA attenuation of hepatic apoptosis in rats with chronic liver disease. Therefore, sorghum/raphia sudanica mesocarp/arrowroot pasta might be useful if incorporated into the daily diet for patients with decompensated liver cirrhosis. The sorghum/arrowroot and sorghum/raphia sudanica mesocarp/arrowroot pasta had 3-fold more BCAAs than conventional durum wheat pasta. Also, the sorghum/raphia sudanica mesocarp/arrowroot pasta had leucine/valine/isoleucine in almost the recommended ratio of 2:1:1 [47] [48].

3.4. Fatty Acids Composition of Composite Spaghetti

The fatty acid composition of *Raphia sudanica* mesocarp oil gave the total concentration of saturated fatty acids as 124.49 mg/100 g (49.74%) and that of unsaturated fatty acids as 125.81 mg/100 g (50.26%) with stearic acid (18.77%) being the predominant saturated fatty acid and linoleic acid (30.09%), the predominant unsaturated fatty acid as shown in **Table 5**. Raphia sudanica mesocarp oil had comparable linoleic (30.85%) and stearic (15.46%) acids content, lower oleic acid content but higher palmitic acid content than African pear oil [49]. The dominance of stearic acid indicates that intake of *raphia sudanica* mesocarp oil may not lead to elevations in plasma total and low density lipoprotein (LDL) cholesterol concentrations, as against lauric, myristic and palmitic fatty acids plasma total and LDL-cholesterol elevating potentials. The combined effect of intake of these saturated fatty acids has shown elevations in total and low density

Table 5. Fatty acid profile of Sorghum/*Tacca involucrata*/*Raphia sudanica* composite spaghetti (mg/100 g).

Fatty acids	AGE1	AGE2	AGE3	AGE4	AGE5	AGE6
SATURATED FATTY ACIDS						
Capric	2.21 ± 0.01^d	2.54 ± 0.01^d	2.95 ± 0.00^{cd}	4.81 ± 0.01^{bc}	6.45 ± 0.01^b	7.04 ± 2.10^a
Lauric	3.07 ± 0.01^f	5.13 ± 0.01^e	6.45 ± 0.00^d	6.94 ± 0.01^c	7.49 ± 0.01^b	10.63 ± 0.01^a
Myristic	3.46 ± 0.01^f	4.53 ± 0.01^e	4.21 ± 0.01^d	5.63 ± 0.01^c	7.56 ± 0.01^b	9.54 ± 0.02^a
Palmitic	7.63 ± 0.01^f	10.63 ± 0.01^e	11.34 ± 0.02^d	19.50 ± 0.00^c	24.25 ± 0.01^b	34.69 ± 0.03^a
Stearic	11.64 ± 0.01^f	15.83 ± 0.01^e	21.45 ± 0.01^d	22.33 ± 0.01^c	22.64 ± 0.01^b	46.97 ± 0.02^a
Arachinic	5.61 ± 0.01^f	6.34 ± 0.01^e	8.05 ± 0.01^d	8.23 ± 0.01^c	9.53 ± 0.01^b	15.62 ± 0.01^a
UNSATURATED FATTY ACIDS						
Oleic	18.35 ± 0.01^f	22.65 ± 0.01^e	25.64 ± 0.01^d	29.05 ± 0.00^c	30.13 ± 0.03^b	50.49 ± 0.02^a
Linoleic	27.78 ± 0.00^f	32.72 ± 0.01^e	35.61 ± 0.01^d	36.22 ± 0.01^c	51.25 ± 0.01^b	75.32 ± 0.01^a

Means in a row with same superscript are significantly not different at $p > 0.05$; AGE1: 250 g sorghum, 0g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE2: 237.5 g sorghum, 12.5 g *Raphia sudanica*, 100 g *Tacca involucrata;* AGE3: 225 g sorghum, 25 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE4: 212.5 g sorghum, 37.5 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE5: 200 g sorghum, 50 g *Raphia sudanica*, 100g *Tacca involucrata;* AGE6: *Raphia sudanica* flour.

lipoprotein cholesterol levels in man. The mesocarp oil showed greater dominance (6) in the number of saturated fatty acids than unsaturated (2) fatty acids. The higher content of both monounsaturated and polyunsaturated (PUFA) fatty acids than saturated fatty acids (SFA) may confer plasma cholesterol-lowering potentials on the composite spaghetti blends. The fact that *Raphia sudanica* mesocarp oil is rich in oleic acid means that the oil is most probably non-drying oil even though it contain more than 50% unsaturated fatty acids. This maybe so because the participation of monounsaturated oleic acid in the drying of oil is limited as oils with more polyunsaturated fatty acids than monounsaturated acids are more susceptible to oxidation and drying and as a rule, only linoleic, linolenic, ricinoleic and *α*-eleostearic acids are constituents of drying oils. The rich monounsaturated oleic acid content of *Raphia sudanica* mesocarp oil may also confer greater oxidative stability than oils containing more polyunsaturated fatty acids. The oil from Raphia sudanica mesocarp flour may make the texture of the spaghetti smoother and silkier. It will also make the dough easily extrude from the pasta machine and enhance the flavour of the spaghetti. High lipid content of pasta containing non-traditional ingredients has been reported to reduce the friction between dough and metal surface inside the extrusion barrel [50]. The use of non-traditional ingredients (with more protein and lipid than semolina) in spaghetti production has been reported to improve its nutritional value and to provide potential health benefits to consumers [51]. The 5% substitution of sorghum flour with *Raphia sudanica* mesocarp flour elevated the fatty acids profile of the composite spaghetti samples. The elevations in saturated fatty acids composition of the composite spaghetti ranged from 2.54 - 6.45 mg/100 g (capric), 5.13 - 7.49 mg/100 g (lauric), 4.53 - 7.56 mg/100 g (myristic), 10.63 - 24.25 mg/100 g (palmitic), 15.83 - 22.64 mg/100 g (stearic) and 6.34 - 9.53 mg/100 g (arachidonic) acids. The elevations in unsaturated fatty acids varied from 22.65 - 30.13 mg/100 g (oleic) and 32.72 - 51.25 mg/100 g (linoleic) acids. The increase in saturated fatty acids with sorghum flour replacement was of the order capric < lauric < myristic < arachidonic < stearic < palmitic while for unsaturated fatty acids was oleic < linoleic.

The elevation in the total lauric, myristic and palmitic acid contents of the composite spaghetti blends may cause elevations in serum total and LDL cholesterol levels as well as decrease in energy utilization. This however, may be countered by the high levels of stearic, oleic and linoleic acids (with higher cholesterol lowering and energy utilizing ability) content of the composite spaghetti samples. The higher cholesterol lowering and sustained energy utilizing ability of stearic, oleic and linoleic acids may be harnessed in treatment of hypercholesterolemia and obesity in man. Substitution of high monounsaturated fatty acids (MUFA) fats for saturated fatty acids (SFA) containing fats in manufactured foods and margarines have also been shown to have beneficial effects on blood cholesterol and other health related outcomes [52]. The fat content of the composite spaghetti comprised of 6 saturated and 2 unsaturated fatty acids of which palmitic and stearic acids represented 46.89 mg/100 g saturated fatty acids while oleic and linoleic acids represented 81.38 mg/100 g of the unsaturated fatty acids. Epidemiological studies have shown that various fatty acids have different biological consequences when ingested singularly or together. Saturated fatty acids in general, and palmitic acid (C16:0) in particular, are harmful in part because they elevate low density lipoprotein cholesterol and atherosclerosis risk [53]. Kien *et al.* [54] reported that intake of a diet containing high-palmitic acid levels caused decreased fat oxidation and increased body fat gain (per unit of energy intake), compared with a high oleic acid diet. The high level of fatty acids in the composite spaghetti is an indication that it may be a major source of the fat-soluble vitamins A, D, E and K, and the carotenoids [55]. However, the unsaturated to saturated fatty acid ratio is 0.50:0.49, while PUFA/SFA ratio is 0.38:0.62 but the Recommended ratio is 0.45 [56].

Sang and Kyung [57] reported that capric acid treatment alleviated inflammatory cytokine production and related gene expression, alleviated oxidative stress and increased oxidative stress-related gene expression in cyclophosphamide-treated IPEC-J2 cells. The permeability of FD-4 and expression of *ZO-1* and *OCLN* in cyclophosphamide-treated IPEC-J2 cells were reduced by capric acid. Dietary capric acid reduced TNF-*α*, IL-6, and MDA levels and increased SOD, GPx, and the expression of genes related to pro-inflammatory, oxidative stress, and intestinal barrier functions in cyclophosphamide-treated miniature pigs. These results revealed that capric acid has protective effects against cyclophosphamide induced small intestinal dysfunction in pigs. The capric acid contents of this study may also confer these health benefits on consumers.

The 11.6 - 22.64 mg/100 g stearic acid contents of this study were higher than

2.3 - 2.5 g/100 g values contained in dry and cooked plain high protein pasta and 2.8 - 12 g/100 g in high protein spinach pasta [58]. Unlike other saturated fatty acids, dietary stearic acid (C18:0) does not increase atherosclerosis risk and, if anything, actually reduces low density lipoprotein cholesterol [53] [59]. Indeed, increased levels of circulating C18:0 lipids are associated with reduced blood pressure, improved heart function, and reduced cancer risk [60] [61]. Hence the higher levels of stearic acid than other saturated fatty acids in *raphia sudanica* mesocarp may appear to confer better metabolic and physiological effects on man, thus impacting some beneficial health effects on consumers. Evidence from human epidemiological and animal studies suggests that stearic acid enhances platelet aggregation in-vitro, indicating its effects on platelet activity, an important aspect of thrombosis and hemostasis [62].

Oleic acid modulates blood pressure, viscosity, transport of cations in erythrocytes [63] and lipid metabolism [64]. It affects numerous enzymatic activities of transport and receptors, as well as desaturation of essential fatty acids [65]. Many studies have shown the influence of the presence of a high level of oleic acid on fatty acid composition of different types of tissues and cells in numerous species [66] and platelets [67].

Arachinic acid (ARA) is an integral constituent of biological cell membrane, conferring it with fluidity and flexibility, so necessary for the function of all cells, especially in nervous system, skeletal muscle, and immune system. Arachinic acid is obtained from food or by desaturation and chain elongation of the plant-rich essential fatty acid, linoleic acid. Free ARA modulates the function of ion channels, several receptors and enzymes, via activation as well as inhibition [68]. ARA is an important component of human milk but is lacking in cow milk and most commercial infant formula in developing countries [69]. Due to its importance in development especially of the central nervous system and retina [70], the Food and Agricultural Organization (FAO)/World Health Organization (WHO) recommended that infant formula, unless specifically added, should be supplemented with ARA [71]. Decreased postnatal ARA blood levels in premature infants were found to be associated with neonatal morbidities, while adding ARA to preterm-infant formulas led to improved visual acuity, visual attention and cognitive development [72] [73].

3.5. Composite Spaghetti Organoleptic Attributes

Table 6 shows mean sensory scores of sorghum/raphia sudanica mesocarp/arrowroot composite spaghetti samples. The acceptability of the composite spaghetti samples decreased with every 5% substitution of sorghum flour with *raphia sudanica* mesocarp flour. Sorghum/arrowroot spaghetti (control) was the most preferred spaghetti by the panelists for all the sensory attributes assessed.

4. Conclusion

Utilization of *Raphia sudanica* mesocarp flour in spaghetti production was feasible. *Raphia sudanica* mesocarp flour may be used to supplement amino and fatty

Table 6. Mean sensory scores of sorghum/*Tacca involucrata*/*Raphia sudanica* composite spaghetti.

Attributes	AGE1	AGE2	AGE3	AGE4	AGE5	Variable mean of 5 samples
Colour	6.25 ± 0.97[a]	4.55 ± 1.14[b]	4.00 ± 1.62[c]	3.20 ± 2.43[d]	3.05 ± 2.35[e]	4.21
Taste	6.05 ± 1.14[a]	4.80 ± 1.32[b]	4.80 ± 1.28[b]	3.15 ± 1.73[c]	3.10 ± 3.20[c]	4.38
Texture	4.80 ± 1.36[a]	4.70 ± 1.49[a]	4.05 ± 1.50a	4.50 ± 1.60[a]	3.85 ± 2.11[a]	4.38
Mouth feel	5.30 ± 1.83[a]	4.80 ± 1.50[b]	4.60 ± 1.43[c]	3.80 ± 1.58[d]	3.85 ± 1.93[d]	4.47
Aroma	5.65 ± 1.18[a]	4.80 ± 1.57[a]	5.65 ± 1.27[a]	4.80 ± 2.04[a]	4.95 ± 2.10[a]	5.17
Acceptability	5.40 ± 1.79[a]	4.50 ± 1.36[b]	4.45 ± 1.43[b]	3.85 ± 1.73[c]	3.30 ± 1.69[d]	4.30
After taste	5.60 ± 1.90[a]	4.70 ± 1.46[b]	4.20 ± 2.21[c]	3.60 ± 1.76[e]	3.40 ± 1.99[e]	4.30

Means in a row with same superscript are significantly not different at $p > 0.05$; AGE1: 250 g sorghum, 0 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE2: 237.5 g sorghum, 12.5 g *Raphia sudanica*, 100 g *Tacca involucrata;* AGE3: 225 g sorghum, 25 g *Raphia sudanica*, 100 g *Tacca involucrate;* AGE4: 212.5 g sorghum, 37.5 g *Raphia sudanica*, 100g *Tacca involucrate;* AGE5: 200 g sorghum, 50g *Raphia sudanica*, 100 g *Tacca involucrata.*

acids in spaghetti and to produce a quick cooking pasta product. Its incorporation in spaghetti production elevated the iron, zinc, potassium, calcium and phytochemical contents of the composite blends but decreased their magnesium and sodium contents. Commercial production of *Raphia sudanica* mesocarp flour is recommended.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Feillet, P. and Dexter, J.E. (1996) Quality Requirements of Durum Wheat for Semolina Milling and Pasta Production. In: Kruger, J.E., Matsuo, R.R. and Dick, J.W., Eds., *Pasta and Noodle Technology*, AACC Inc., 95-123.

[2] Novaro, P., D'Egidio, M.G., Mariani, B.M. and Nardi, S. (1993) Combined Effects of Protein Content and High Temperature Drying Systems on Pasta Cooking Quality. *Cereal Chemistry*, **70**, 716-719.

[3] Chillo, S., Laverse, J., Falcone, P.M., Protopapa, A. and Del Nobile, M.A. (2008) Influence of the Addition of Buckwheat Flour and Durum Wheat Bran on Spaghetti Quality. *Journal of Cereal Science*, **47**, 144-152. https://doi.org/10.1016/j.jcs.2007.03.004

[4] Alamprese, C., Rossi, M. and Casiraghi, E. (2004) Hygienic Quality Evaluation of the Egg Product Used as Ingredient in Fresh Egg Pasta. *Food Chemistry*, **87**, 313-319. https://doi.org/10.1016/j.foodchem.2003.12.030

[5] Caperuto, L., Amaya-Farfan, J. and Camargo, C.R.O. (2001) Performance of Quinoa (*Chenopodium quinoa* Willd) Flour in the Manufacture of Gluten-Free Spaghetti. *Journal of the Science of Food and Agriculture*, **81**, 95-101. https://doi.org/10.1002/1097-0010(20010101)81:1<95::AID-JSFA786>3.0.CO;2-T

[6] Elli, L., Branchi, F., Tomba, C., Villalta, D., Norsa, L., Ferretti, F., Roncoroni, L. and

Bardella, M.T. (2015) Diagnosis of Gluten Related Disorders: Celiac Disease, Wheat a Allergy and Non-Celiac Gluten Sensitivity. *World Journal of Gastroenterology*, **21**, 7110-7119. https://doi.org/10.3748/wjg.v21.i23.7110

[7] Ludvigsson, J.F., Bai, J.C., Biagi, F., Card, T.R., Ciacci, C., Ciclitira, P.J., Green, P.H., Hadjivassiliou, M., Holdoway, A., van Heel, D.A., Kaukinen, K., Leffler, D.A., Leonard, J.N., Lundin, K.E., McGough, N., Davidson, M., Murray, J.A., Swift, G.L., Walker, M.M., Zingone, F. and Sanders, D.S. (2014) Diagnosis and Management of Adult Celiac Disease: Guidelines from the British Society of Gastroenterology. *Gut*, **63**, 1210-1228. https://doi.org/10.1136/gutjnl-2013-306578

[8] Gallagher, E., Gormley, T.R. and Arendt, E.K. (2004) Recent Advances in the Formulation of Gluten-Free Cereal-Based Products. *Trends in Food Science Technology*, **15**, 143-152. https://doi.org/10.1016/j.tifs.2003.09.012

[9] Lohiniemi, S., Maki, M., Kaukinen, K., Laippala, P. and Collin, P. (2000) Gastrointestinal Symptoms Rating Scale in Celiac Patients on Wheat Starch-Based Gluten-Free Diets. *Scandinavia Journal of Gastroenterology*, **35**, 947-949. https://doi.org/10.1080/003655200750023002

[10] uszczak, L., Witczak, T., Ziobro, R., Korus, J., Cieślik, E. and Witczak, M. (2012) Effect of Inulin on Rheological and Thermal Properties of Gluten-Free Dough. *Carbohydrate Polymers*, **90**, 353-360. https://doi.org/10.1016/j.carbpol.2012.04.071

[11] Islas-Rubio, A.R., Calderón de la Barca, A.M., Cabrera-Chávez, F., Cota-Gastélum, A.G. and Beta, T. (2014) Effect of Semolina Replacement with a Raw: Popped Amaranth Flour Blend on Cooking Quality and Texture of Pasta. *Food Science and Technology*, **57**, 217-222. https://doi.org/10.1016/j.lwt.2014.01.014

[12] Foschia, M., Peressini, D., Sensidoni, A. and Brennan, C.S. (2013) The Effects of Dietary Fibre Addition on the Quality of Common Cereal Products. *Journal of Cereal Science*, **58**, 216-227. https://doi.org/10.1016/j.jcs.2013.05.010

[13] Chand, A., Eyles, H. and Ni Mhurchu, C. (2012) Availability and Accessibility of Healthier Options and Nutrition Information at New Zealand Fast Food Restaurants. Appetite, **58**, 227-233. https://doi.org/10.1016/j.appet.2011.10.006

[14] Komatsu, T.R., Buriti, F.C.A., da Silva, R.C., Lobo, A.R., Colli, C., Gioielli, L.A. and Saad, S.M.I. (2013) Nutrition Claims for Functional Guava Mousses Produced with Milk Fat Substitution by Inulin and/or Whey Protein Concentrate Based on Heterogeneous Food Legislations. *Food Science and Technology*, **50**, 755-765. https://doi.org/10.1016/j.lwt.2012.07.013

[15] Gravel, K., Doucet, É., Herman, C.P., Pomerleau, S., Bourlaud, A.S. and Provencher, V. (2012) Healthy, Diet, or Hedonic. How Nutrition Claims Affect Food-Related Perceptions and Intake? *Appetite*, **59**, 877-884. https://doi.org/10.1016/j.appet.2012.08.028

[16] Saravana, M. and Soam, S.K. (2010) Exploitation of Minor Millets Genetic Resources for Poverty Alleviation in India. *National Conference on Biodiversity, Development and Poverty Alleviation*, Lucknow, 22 May 2010, 75, 61-69.

[17] Licata, R., Chu, J., Wang, S., Coorey, R., James, A., Zhao, Y. and Johnson, S. (2013) Determination of Formulation and Processing Factors Affecting Slowly Digestible Starch, Protein Digestibility and Antioxidant Capacity of Extruded Sorghum-Maize Composite Flour. *International Journal of Food Science & Technology*, **49**, 1408-1419.

[18] Ezeogu, L.I., Duodu, K.G. and Taylor, J.R.N. (2005) Effects of Endosperm Texture and Cooking Conditions on the *In-Vitro* Starch Digestibility of Sorghum and Maize Flours. *Journal of Cereal Science*, **42**, 33-44. https://doi.org/10.1016/j.jcs.2005.02.002

[19] Suherndro, E.L., Kunetz, C.F., Mcdonough, C.M. and Wanshika, R.D. (2000) Cooking Characteristics and Quality of Noodles from Food Sorghum. *Cereal Chemistry*, **77**, 96-100. https://doi.org/10.1094/CCHEM.2000.77.2.96

[20] Liu, L., Herald, T.J, Wang, D., Wilson, J.D., Bean, W. and Aramouni, F.M. (2012) Characterization of Sorghum Grain and Evaluation of Sorghum Flour in a Chinese Egg Noodle System. *Journal of Cereal Science*, **55**, 31-36. https://doi.org/10.1016/j.jcs.2011.09.007

[21] Faure, J.C. (1992) Sorghum and Maize Pasta and Extruded Products. In: Gomez, M.I., House, L.R., Rooney, L.W. and Dendy, D.A.V. Eds., *Utilization of Sorghum and Millets*, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, 75-82.

[22] Otedoh, M.O. (1990) Sweet Raffia Palm Wine. *The Nigerian Field*, **55**, 59-64.

[23] Bosha, J.A., Anaga, A.O. and Asuzu, I.U. (2015) Chemical Composition of the Marc of a Wild Tropical Plant *Tacca involucrata* (Schumach and Thonn, 1827). *Food and Nutrition Sciences*, **6**, 135-140. https://doi.org/10.4236/fns.2015.61014

[24] Burkil, H.M. (1994) The Useful Plants of West Tropical Africa. Royal Botanic Gardens, Kew, 70-76.

[25] Liu, Q., Donner, E., Yin, Y., Huang, R.L. and Fan, M.Z. (2006) The Physicochemical Properties and *In-Vitro* Digestibility of Selected Cereals, Tubers, and Legumes Grown in China. *Food Chemistry*, **99**, 470-477. https://doi.org/10.1016/j.foodchem.2005.08.008

[26] Hung, P.V. and Morita, N. (2005) Physicochemical Properties and Enzymatic Digestibility of Starch from Edible Canna (*Canna edulis*) Grown in Vietnam. *Carbohydrates Polymer*, **61**, 314-321. https://doi.org/10.1016/j.carbpol.2005.04.021

[27] Sudha, M.L. and Leelavathi, K. (2012) Effect of Blends of Dehydrated Green Pea Flour and Amaranth Seed Flour on the Rheological, Microstructure and Pasta Making Quality. *Journal of Food Science and Technology*, **49**, 713-720. https://doi.org/10.1007/s13197-010-0213-z

[28] AOAC (2000) Association of Official Analytical Chemist. 18th Edition, Official Methods of Analytical Chemist, Washington DC.

[29] Laxmi, V., Bhatia, A.K., Goel, A., Wahi, N. and Sharma, A. (**2015**). Phytochemicals Screening and Analysis Using HPLC to Determine the Antimicrobial Efficacy of *Cassia fistula* Extract. *Advances in Bioresearch*, **6**, 1-7.

[30] Rioux, V., Catheline, D., Bouriel, M. and Legrand, P. (1999) High Performance Liquid Chromatography of Fatty Acids as Naphthacyl Derivatives. *Analusis*, **27**, 186-193. https://doi.org/10.1051/analusis:1999165

[31] Woo, K. (2000) Determination of Amino Acids in Foods by Reversed-Phase High-Performance Liquid Chromatography with New Precolumn Derivatives, Butylthiocarbamyl, and Benzylthiocarbamyl Derivatives Compared to the Phenylthiocarbamyl Derivative and Ion Exchange Chromatography. In: Cooper, C., Packer, N. and Williams, K., Eds., *Amino Acid Analysis Protocols*, Humana Press, 141-167.

[32] ISO (2003) Animal and Vegetable Fats and Oils Determination. 12, 45-49.

[33] Muhimbula, H.S., Issa-Zacharia, A. and Kinabo, J. (2011) Formulation and Sensory Evaluation of Complementary Foods from Local, Cheap and Readily Available Cereals and Legumes in Iringa, Tanzania. *African Journal of Food Science*, **5**, 26-31.

[34] Ikujenlola, A.V. (2015) High Nutrient Dense Pastas from Quality Protein Maize, Sorghum and Watermelon Seed Flour: Chemical Composition, *In-Vitro* Protein Digestibility and Sensory Properties. *Proceedings of the Obafemi Awolowo Univer-*

sity, Faculty of Technology Conference, Ile-Ife, Vol. 11, 45-49.

[35] Petru, B.R., Ersilia, A., Isidora, R., Atila, M., Cristiana, S.S.M. and Teodor I.T. (2015) Total Phenolic, Cinnamic Aids and Selected Microelements in Gluten Free Pasta Fortified with Banana. *Revista de Chimie-Bucharest Original Edition*, **66**, 1162-1165.

[36] Panceri, C.P., Gomes, T.M., De Gois, J.S., Borges, D.L.G. and Bordignon-Luiz, M.T. (2013) Effect of Dehydration Process on Mineral Content, Phenolic Compounds and Antioxidant Activity of Cabernet Sauvignon and Merlot Grapes. *Food Research International*, **54**, 1343-1350. https://doi.org/10.1016/j.foodres.2013.10.016

[37] Ahmed, M.S.H., Mohie, M.K. and Gama, F.M. (2011) Phytochemical and Sensorial Quality of Semolina-Defatted Guava Seeds Flour Composite Pasta. *Journal of American Science*, **7**, 623-627.

[38] Krishna, G.G. and Kapoor, S.C. (1991) Potassium Depletion Exacerbates Essential Hypertension. *Annual International Medicine*, **115**, 77-83. https://doi.org/10.7326/0003-4819-115-2-77

[39] Reddy, K.S. and Katan, M.B. (2004) Diet, Nutrition and the Prevention of Hypertension and Cardiovascular Diseases. *Public Health Nutrition*, **7**, 167-186. https://doi.org/10.1079/PHN2003587

[40] Curhan, G.C., Willett, W.C., Speizer, F.E., Spiegelman, D. and Stampfer, M.J. (1997) Comparison of Dietary Calcium with Supplemental Calcium and Other Nutrients as Factors Affecting the Risk for Kidney Stones in Women. *Annals of Internal Medicine*, **126**, 497-504. https://doi.org/10.7326/0003-4819-126-7-199704010-00001

[41] Curhan, G.C., Willett, W.C., Rimm, E.B. and Stampfer, M.J. (1993) A Prospective Study of Dietary Calcium and Other Nutrients and the Risk of Symptomatic Kidney Diseases. *New England Journal of Medicine*, **328**, 833-838. https://doi.org/10.1056/NEJM199303253281203

[42] Cook, N.R., Kumanyika, S.K., Cutler, J.A. and Whelton, P.K. (2005) Trials of Hypertension Prevention Collaborative Research Group (TOHP). Dose-Response of Sodium Excretion and Blood Pressure Change among Overweight Non-Hypertensive Adults in a Three-Year Dietary Intervention Study. *Journal of Human Hypertension*, **19**, 47-54. https://doi.org/10.1038/sj.jhh.1001775

[43] Francisco, P. and Juan, D. (2010) Flavoniods and Cardiovascular Diseases. *Journal of Molecular Aspects of Medicine*, **31**, 478-494. https://doi.org/10.1016/j.mam.2010.09.002

[44] Shogren, R.L., Hareland, G.A. and Wu, Y.V. (2006) Sensory Evaluation and Composition of Spaghetti Fortified with Soy Flour. *Journal of Food Science*, **71**, 428-432. https://doi.org/10.1111/j.1750-3841.2006.00061.x

[45] Aquilani, R., Boselli, M., Boschi, F., Viglio, S., Iadarola, P. and Dossena, M. (2008) Branched-Chain Amino Acids May Improve Recovery from a Vegetative or Minimally Conscious State in Patients with Traumatic Brain Injury: A Pilot Study. *Archives of Physiology and Medical Rehabilitation*, **89**, 1642-167. https://doi.org/10.1016/j.apmr.2008.02.023

[46] Kawaguchi, T., Shiraishi, K., Ito, T., Suzuki, K., Koreeda, C. and Ohtake, T. (2014) Branched-Chain Amino Acids Prevent Hepatocarcinogenesis and Prolong Survival of Patients with Cirrhosis. *Clinical, Gastroenterology and Hepatology*, **12**, 1012-1018. https://doi.org/10.1016/j.cgh.2013.08.050

[47] Kuwahata, M., Kubota, H., Kanouchi, H., Ito, S., Ogawa, A., Kobayashi, Y. and Kido, Y. (2012) Supplementation with Branched-Chain Amino Acids Attenuates Hepatic Apoptosis in Rats with Chronic Liver Disease. *Nutrition Research*, **32**,

522-529. https://doi.org/10.1016/j.nutres.2012.06.007

[48] Takeshita, S., Ichikawa, T., Nakao, K., Miyaaki, H., Shibata, H. and Matsuzaki, T. (2009) A Snack Enriched with Oral Branched-Chain Amino Acids Prevents a Fall in Albumin in Patients with Liver Cirrhosis Undergoing Chemoembolization for Hepatocellular Carcinoma. *Nutrition Research*, **29**, 89-93. https://doi.org/10.1016/j.nutres.2008.12.005

[49] Scognamiglio, R., Negut, C., Piccolotto, R., Dioguardi, F.S., Tiengo, A. and Avogaro, A. (2004) Effects of Oral Amino Acid Supplementation on Myocardial Function in Patients with Type 2 Diabetes Mellitus. *American Heart Journal*, **147**, 1106-1112. https://doi.org/10.1016/j.ahj.2003.12.003

[50] Aquilani, R., Zuccarelli, G.C., Dioguardi, F.S., Baiardi, P., Frustaglia, A. and Rutili, C. (2011) Effects of Oral Amino Acid Supplementation on Long-Term-Care-Acquired Infections in Elderly Patients. *Archive of Gerontology and Geriatric*, **52**, e123-e128. https://doi.org/10.1016/j.archger.2010.09.005

[51] Ikhuoria, E.U. and Maliki, M. (2007) Characterization of Avocado Pear (*Persea americana*) and African Pear (*Dacryodes edulis*) Extracts. *African Journal of Biotechnology*, **7**, 950-954.

[52] Fuad, T. and Prabhasankar, P. (2010) Role of Ingredients in Pasta Product Quality: A Review on Recent Developments. *Critical Reviews in Food Science and Nutrition*, **50**, 787-798. https://doi.org/10.1080/10408390903001693

[53] Yalla, S.R. and Manthey, F.A. (2006) Effect of Semolina and Absorption Level on Extrusion of Spaghetti Containing Non-Traditional Ingredients. *Journal of Science, Food and Agriculture*, **6**, 841-848. https://doi.org/10.1002/jsfa.2425

[54] Williams, C.M., Francis-Knapper, J.A., Webb, D., Brookes, C.A., Zampelas, A., Tredger, J.A., Wright, J., Calder, P.C., Yaqoob, P., Roche, H. and Gibney, M.J. (1999) Cholesterol Reduction Using Manufactured Foods High in Monounsaturated Fatty Acids; A Randomized Cross-Over Study. *British Journal of Nutrition*, **81**, 439-446.

[55] Siri-Tarino, P.W., Sun, Q., Hu, F.B. and Krauss, R.M. (2010) Saturated Fatty Acids and Risk of Coronary Heart Disease: Modulation by Replacement Nutrients. *Current Atherosclerosis Reports*, **12**, 384-390. https://doi.org/10.1007/s11883-010-0131-6

[56] Kien, C.L., Bunn, J.Y. and Ugrasbul, F. (2005) Increasing Dietary Palmitic Acid Decreases Fat Oxidation and Daily Energy Expenditure. *American Journal of Clinical Nutrition*, **82**, 320-326. https://doi.org/10.1093/ajcn/82.2.320

[57] Jan, M., Filip, S., Polak, T., Hribar, J. and Vidrih, R. (2011) Quantitative Comparison of the Fatty Acid Composition of Dairy and Artificial Creams and Their Nutritional Value in the Human Diet. *Milchwissenschaft*, 66, 186-189.

[58] Polak, T., Rajar, A., Gašperlin, L. and Žlender, B. (2008) Cholesterol Concentration and Fatty Acid Profile of Red Deer (Cervus elaphus) Meat. *Meat Science*, **80**, 864-869. https://doi.org/10.1016/j.meatsci.2008.04.005

[59] Sang, I.L. and Kyung, S.K. (2017) Function of Capric Acid in Cyclophosphamide-Induced Intestinal Inflammation, Oxidative Stress, and Barrier Function in Pigs. *Scientific Reports*, **7**, 1-12.

[60] Petitot, M., Boyer, L., Miner, C. and Micord, V. (2009) Fortification of Pasta with Split Pea and Faba Bean Flours; Pasta Processing and Quality Evaluation. *Food Research International*, **43**, 634-641. https://doi.org/10.1016/j.foodres.2009.07.020

[61] Hunter, J.E., Zhang, J. and Kris-Etherton, P.M. (2010) Cardiovascular Disease Risk

of Dietary Stearic Acid Compared with Trans, Other Saturated and Unsaturated Fatty Acids: A Systematic Review. *American Journal of Clinical Nutrition*, **91**, 46-63. https://doi.org/10.3945/ajcn.2009.27661

[62] Kris-Etherton, P.M., Griel, A.E., Psota, T.L., Gebauer, S.K., Zhang, J. and Etherton, T.D. (2005) Dietary Stearic Acid and Risk of Cardiovascular Disease: Intake, Sources, Digestion, and Absorption. *Lipids*, **40**, 1193-1200. https://doi.org/10.1007/s11745-005-1485-y

[63] Cross, A.J., Moore, S.C., Boca, S., Huang, W.Y., Xiong, X., Stolzenberg-Solomon, R., Sinha, R. and Sampson, J.N. (2014) A Prospective Study of Serum Metabolites and Colorectal Cancer Risk. *Cancer*, **120**, 3049-3057. https://doi.org/10.1002/cncr.28799

[64] Hoak, J.C. (1994). Stearic Acid, Clotting and Thrombosis. *American Journal of Clinical Nutrition*, **60**, 1050S-1053S. https://doi.org/10.1093/ajcn/60.6.1050S

[65] Sacks, F.M., Stampfer, M.J., Munoz, A., McManus, K., Canessa, M. and Kass, E.H. (1987) Effect of Linoleic and Oleic Acids on Blood Pressure, Blood Viscosity, and Erythrocyte Cation Transport. *Journal of American College of Nutrition*, **6**, 179-185. https://doi.org/10.1080/07315724.1987.10720179

[66] Lu, Y.F. and Wu, H.L. (1994) Effect of Monounsaturated Fatty Acids under Fixed P/S and n-6/n-3 Ratios on Lipid Metabolism in Rats. *Journal of Nutritional Sciences and Vitaminology*, **40**, 189-200. https://doi.org/10.3177/jnsv.40.189

[67] Giron, M.D., Mataix, F.J., Faus, M.J. and Suarez, M.D. (1989) Effect of Long-Term Feeding Olive and Sunflower Oils on Fatty Acid Composition and Desaturation Activities of Liver Microsomes. *Biochemistry International*, **19**, 645-656.

[68] Periago, J.L., De Lucchi, C., Gil, A., Suarez, M.D. and Pita, M.L. (1998) Lipid Composition of Liver Microsomes in Rats Fed a High Monounsaturated Fatty Acid Diet. *Biochemistry and Biophysics Acta*, **962**, 66-72. https://doi.org/10.1016/0005-2760(88)90096-3

[69] Vognild, E., Elvevoll, E.O., Brox, J., Olsen, R.L., Barstad, H., Aursand, M. and Osterud, B. (1998) Effects of Dietary Marine Oils and Olive Oil on Fatty Acid Composition, Platelet Membrane Fluidity, Platelet Responses, and Serum Lipids in Healthy Humans. *Lipids*, **33**, 427-436. https://doi.org/10.1007/s11745-998-0224-8

[70] Tallima, H. and El Ridi, R. (2018) Arachidonic Acid: Physiological Roles and Potential Health Benefits—A Review. *Journal of Advanced Research*, **11**, 33-41. https://doi.org/10.1016/j.jare.2017.11.004

[71] Innis, S.M. (2014) Impact of Maternal Diet on Human Milk Composition and Neurological Development of Infants. *American Journal of Clinical Nutrition*, **99**, 734S-741S. https://doi.org/10.3945/ajcn.113.072595

[72] Crawford, M.A., Costeloe, K., Ghebremeskel, K., Phylactos, A., Skirvin, L. and Stacey, F. (1997) Are Deficits of Arachidonic and Docosahexaenoic Acids Responsible for the Neural and Vascular Complications of Preterm Babies? *American Journal of Clinical Nutrition*, **66**, 1032S-1041S. https://doi.org/10.1093/ajcn/66.4.1032S

[73] WHO/FAO (1995) Fats and Oils in Human Nutrition. *Nutrition Reviews*, **53**, 202-205.

Plate 1. Spaghetti samples immediately after extrution.