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Effect of drum drying on the physical and chemical characteristics of instant cereal mixes from the blends of millet and sesame fortified with moringa leaf powder

***Adgidzi, E. A.[12], and Ani, J. C.[1]**
[1]*Department of Food Science and Technology, University of Nigeria, Nsukka, Enugu State, Nigeria.*
[2]*Department of Home Science and Management, Faculty of Agriculture. Shabu-Lafia Campus. PMB135. Nasarawa State University, Keffi, Nasarawa State.*

***Correspondence author:** *euniceadgidzia@gmail.com Telephone Number: +2348036491409*

Abstract
The effect of drum drying on the physical and chemical characteristics of instant cereal mixes (ICM) from the blends of millet and sesame fortified with Moringa Leaf Powder (MLP) was investigated. Unfortified instant cereal mixes (uICM) were produced from graded levels of dehulled 0.75 % citric acid depigmented millet (100, 95, 90, 85 and 80 %) and dehulled sesame seed (0, 5, 10, 15, and 20 %), while fortified ICM (fICM) from graded levels of dehulled 0.75 % citric acid depigmented millet (95, 90, 85, 80, and 75 %), dehulled sesame seed (0, 5, 10, 15, and 20 %) and MLP (5 %). Slurries of blends was fed to drum drier to produce ICM and evaluated for physical and chemical properties. The MLP (25.33 %) and DSF (24.19 %) had comparable crude protein contents. The total ash and ether extract contents of DSF was 3.09 and 49.85 %, while MLP had 8.57 and 4.82 %, respectively. The fICM had decreased whiteness values (70.27 to 64.60), while uICM showed increased whiteness (78.18 to 80.77) values. The chemical composition of ICM showed increases in ash (0.68 to 1.75 %), protein (8.05 to 12.74 %), total dietary fiber (0.10 to 16.44 %), pro vitamin A (666.85 to 1184.30 µg/100g) contents and amino acids concentrations which increased with sesame and MLP inclusion. fICM showed higher concentration of amino acids, crude protein, total ash, and total dietary fiber than control sample while uICM showed higher L values than fICM.*

Keywords: *Blends of millet and sesame; Drum drying; Fortified; Instant cereal mix; Moringa Leaf Powder*

Introduction

In Nigeria and most developing nations, breakfast cereals are often referred to as hot-serve breakfast cereals in the form of porridges or gruels and served hot. Originally, hot-serve or traditional breakfast cereals were made from wheat, rice and corn (maize) but, other cereals such as millet, sorghum, fonio ('acha') are also being used. These cereals are mostly used whole or in such other forms as grits, meals and flours for breakfast. Hot-serve breakfast cereals are typically grouped according to the time required for preparation. The 30 minutes group are referred to as old fashioned meals, 1-15minutes group are called the quick meals and the group that require hot or cold water addition without cooking are known as instant meals (Tribelhorn, 1991; Anderson, 2013).

Recently, efforts to reduce the amount of preparation time, breakfast cereal technology has evolved from the simple procedure of milling grains for cereal products that require cooking to highly sophisticated ready to eat products that are convenient and quickly prepared. Most indigenous breakfast foods such as 'kunun ridi', and 'akamu' or 'ogi' are non-shelf stable porridges that involve cooking before consumption. Maize, wheat and rice are the most commonly used grains, occasionally complemented with grain legumes. There are other grains such as millet, sorghum, fonio and sesame that can be used. Soybeans and maize may be limited for use as raw materials in breakfast cereals production because they have found so much use in a number of industrial products and household purposes, such that their use for additional purposes may limit availability and consequently may not be cost effective (Mbaeyi, 2005). Meanwhile there are other raw materials whose potentials as alternatives need to be exploited, among such possible alternatives is millet (*Pennisetum glaucum*). The FAO statistics for 2019 reported that Nigeria is the 4th producer of millet with production statistics of 2,000,000 metric tons (www. tilasto.com), but this grain has not found much industrial use presently in Nigeria. Other locally available nutrient rich agricultural produce that can serve as sources of the much needed protein and micronutrients are sesame and moringa. Industrial processing and utilization of sesame have not been fully developed in Nigeria though, it contains 20-25% protein, 40-50% oil, 18-20% carbohydrates and 5-6% ash (Chemonics International, 2002; Gandhi and Srivastana, 2007). It is also rich in sulphur containing amino acids, tryptophan and methionine. Less than 5% of the annual production of millets is commercially processed by industries, even when attempts have been made, it has been difficult to utilize millet because of the lack of adequate technology required to harness its industrial potentials (Obilana and Manyasa, 2002). This negative trend may be addressed in several ways through development of new food products, value addition, and improvement of traditional food products from millet and fabrication of machines or equipment to aid processing of millet (Oduori, 2005). Value addition of foods refers to conversion of commodities into processed foods which are usually more stable and more marketable than the raw unprocessed commodities (Nkama *et al.* 2010). The combination of sesame and moringa leaf with millet for breakfast food development has not been fully investigated. There is need to produce quality acceptable breakfast food from blends of depigmented millet and sesame fortified with moringa leaf powder. Sesame is rich in minerals, protein and oil with anti-cholesterol properties, but has limited industrial food application. Moringa leaf powder (MLP) is a micronutrient rich vegetable recommended as a fortificant to ameliorate hidden hunger. Inclusion of MLP will enhance nutrient content of millet-sesame based breakfast food. Adgidzi and Ani, (2019) reported that ready to eat (RTE) millet-based foods like ‘fura’ have been processed by extrusion technology and suggested that other processing technologies, such as drum drying can be used to provide consumers with variety and put food in RTE form.

It is envisaged that this study will address the problem of malnutrition while at the same time provide the much needed convenience by putting foods in a form that can ensure regular and sustained supply.

The use of agricultural produce such as millet, sesame, and moringa will be diversified. There will also be diet diversification and enhancement of the availability of foods from this unexploited grain beyond the area and the season of production.

Consequently, there will be value addition to sesame, millet and *Moringa oleifera*, thus stabilizing supplies, increasing income and food security at various levels that is. urban and rural communities.

Materials and Methods

Materials

Millet and sesame were purchased from Alamis market, Lafia in Nasarawa State while moringa leaves were harvested from

College of Agriculture residential quarters, Lafia.

Preparation of dehulled millet, dehulled sesame and moringa leaf powder

Millet grains were cleaned and conditioned for 15min using water and dehulled using traditional method, mortar and pestle. Furthermore, the grains were sun dried and winnowed using raffia trays to separate bran from the dehulled grains Sesame were cleaned and dehulled by floatation method followed by soaking in salt solution (3% NaCl) for 17-18hr (NAERLS, 2011). Moringa leaf powder was produced by method described by de Saint Sauver, 2010.

Table 1. Formulation of instant cereal mixes (%) from blends of depigmented dehulled millet, sesame and moringa leaf powder

Sample	Dehulled Millet	Dehulled sesame	MLP
ICMQ	100	0	0
ICMA	95	5	0
ICMB	90	10	0
ICMC	85	15	0
ICMK	80	20	0
ICMG	90	5	5
ICMH	85	10	5
ICMI	80	15	5
ICMM	75	20	5

LEGEND

ICMQ - 100% drum dried millet flour from dehulled millet soaked in 0.75% citric acid
ICMA - Instant cereal mix from 95% dehulled millet soaked in 0.75% citric acid + 5% dehulled sesame
ICMB - Instant cereal mix from 90% dehulled millet soaked in 0.75% citric acid + 10% dehulled sesame
ICMC - Instant cereal mix from 85% dehulled millet soaked in 0.75% citric acid + 15% dehulled sesame
ICMK - Instant cereal mix from 80% dehulled millet soaked in 0.75% citric acid + 20% dehulled sesame
ICMG - Instant cereal mix from 90% dehulled millet soaked in 0.75% citric acid + 5% dehulled sesame + 5% MLP
ICMH - Instant cereal mix from 85% dehulled millet soaked in 0.75% citric acid + 10% dehulled sesame + 5% MLP
ICMI - Instant cereal mix from 80% dehulled millet soaked in 0.75% citric acid + 15% dehulled sesame + 5% MLP
ICMM - Instant cereal mix from 75% dehulled millet soaked in 0.75% citric acid + 20% dehulled sesame + 5% MLP

Preparation of instant cereal mix (ICM) from blends of dehulled millet, dehulled sesame and moringa leaf powder

Dehulled sesame flour (DSF) was processed from ground dehulled sesame while MLP was from shade dried pulverized moringa leaves. Unfortified ICM was produced from graded levels of 0.75 % citric acid depigmented millet (100, 95, 90, 85 and 80 %) and dehulled sesame seed (0, 5, 10, 15, and 20 %), while fortified ICM from graded levels of 0.75 % citric acid depigmented millet (95, 90, 85, 80, and 75 %), dehulled sesame seed (0, 5, 10, 15, and 20 %) and MLP (5 %). Each blend was slurried, screened through a 710μm sieve and drum dried at 2 bars pressure, 120.2^{o}C, 2 rpm rotating speed (of drums) and feed gap of 0.2 mm using Double drum dryer (R. Simon (dryer) LTD, Nottingham England). Dehulled sesame was incorporated within 5 to 20% because of the high oil content (48.85%) while (MLP) was used at 5% level based on the recommendations of Carew *et al*., (2012). Production of instant cereal mix is shown in Figure.1

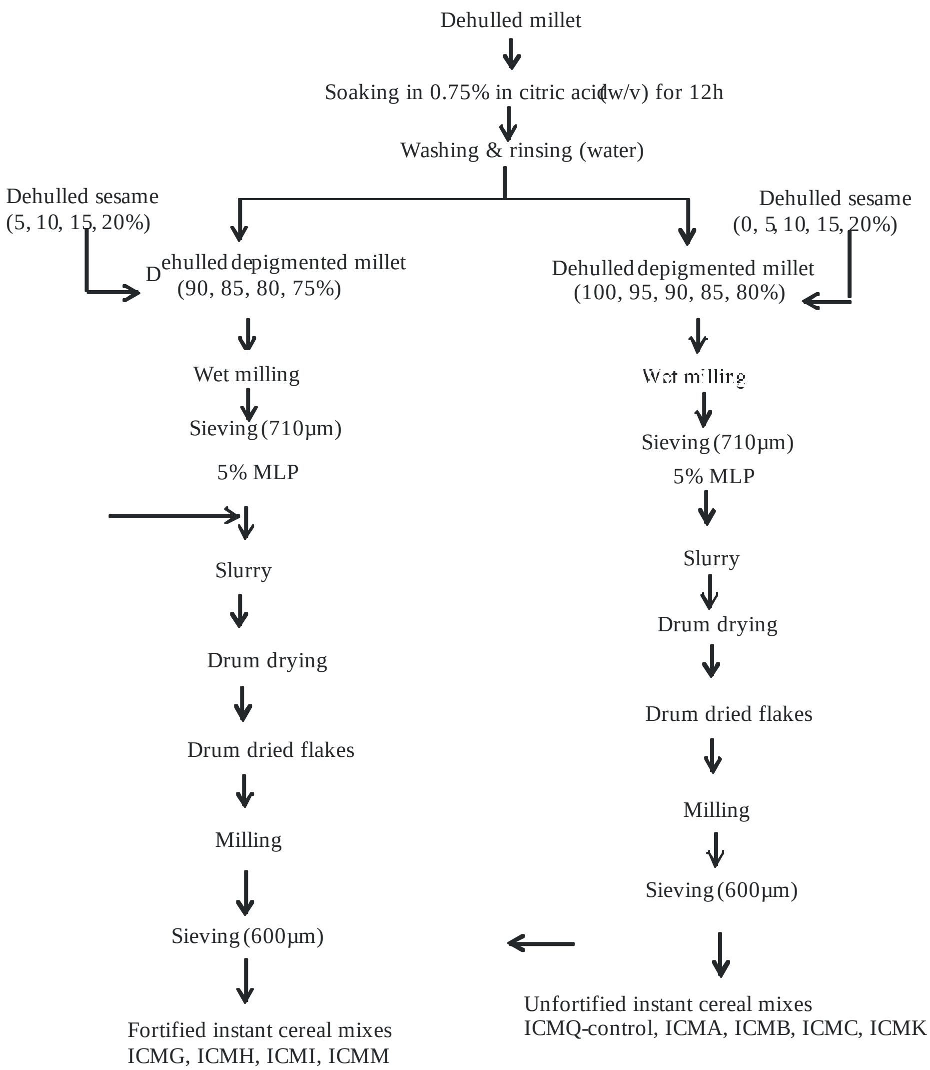

Fig.1. Flow chart for the production of instant cereal mixes from blends of 0.75% citric acid depigmented millet, dehulled sesame and moringa leaf powder

Physical analysis

Bulk density: Bulk density was determined by the method of Okaka and Potter (1979).

Water absorption capacity (WAC): Water absorption capacity was determined by the modified method of Gandhi and Srivastava, (2007).

Swelling power: Swelling power was determined as described by Leach *et al.*, (1959).

Colour: The colour of instant cereal mixes were measured using HunterLab Colorimeter (UltraScan PRO, USA). Samples were put into an optically transparent glass cell, CIELAB value readings were taken. The L* is a measure of lightness ranging from 0 (black) to

(100) white, the a* value ranges from - (greenness) to + (redness) and the b* value ranges from - (blueness) to + (yellowness).

Particle size analysis: The particle sizes of instant cereal mixes was determined using the method described by Adgidzi *et al*, (2018) with a laser particle size analyzer (Mastersizer 2000, Malvern Instrument LTD, Malvern UK).

Chemical Analysis

Ash content, Ether Extract, Crude fiber, Moisture Content and Crude protein were evaluated according to (AOAC, 2010).

Total Dietary Fiber (AOAC, 2010)

Celite 545 (0.5g) was added to crucibles and ashed for 3h at 525^oC in a muffle furnace. Crucibles were cooled for approximately 1h in desiccators and weighed. One gram of sample was weighed in duplicates and transferred quantitatively to properly cleaned flask and covered with aluminum foil. MES-TRIS buffer (40ml) solution of pH 8.2 was added to each flask, stirred on a magnetic stirrer until sample was completely dispersed. A volume (100μl) of α-amylase was added to the flask with stirring at low speed, covered with aluminum foil and incubated at 95^oC in a waterbath for 30min. After 30min, the flasks were removed from the waterbath and the flasks were cooled to 60^oC , the aluminum foil was removed from the flask, rings found in the flask were scraped into the solution and gels formed in the bottom of the flask was dispersed with rubber spatula. Walls of flask were rinsed with 10ml water and 100μl of protease was added to each flask. The flasks were covered with aluminum foil and incubated for 30min at 60^oC with continuous agitation. The aluminum foil was removed, 5ml of 0.561N HCl was dispensed into each flask while stirring and pH was adjusted to 4.0-4.7 at 60^oC. Amyloglucosidase (200μl) was also added with continuous stirring, after which the flasks were covered with aluminum foil and incubated for 30min at 60^oC with continuous agitation.

Following digestion, 225ml of 95% ethanol was added to each digested sample which was removed from the water-bath covered with aluminum foil and allowed to precipitate for 1h at room temperature. Celite bed in previously tarred crucible was wetted and redistributed using 15ml 78% ethanol. Suction was applied to draw celite onto fritted glass as an even mat. The crucible and incubation flasks were attached to the Fibertec E filtration module. Alcohol treated enzyme digest was filtered through the crucible, the residue rinsed with 78% ethanol and transferred to the crucible. The residues were washed two times each with 15ml of 78% ethanol and 95% ethanol. Crucible was removed from upper suction and washed with two 15ml portions of acetone, dried over night at 105^oC and cooled in the desiccators for 1h. Crucible containing dietary fiber residue and celite 545 was weighed, the residue weight was calculated by subtracting weight of dry crucible with celite 545.

The first duplicates were used for protein determination. Sample, celite 545 and fiber mat were scraped into digestion tube for protein analysis. The second set of duplicate was incinerated at 525^oC, crucible and celite 545 was subtracted to determine ash using the expression,

$$\text{Blank weight (B) (mg)} = \frac{BR^1 + BR^2 - B^{protein} - B^{ash}}{2}$$

$$\text{Total dietary fiber (TDF) (mg)} = \frac{R^1 + R^2 - mg^{\,protein} - mg^{\,ash} - B \times 100}{\frac{M^1 + M^2}{B}}$$

Where; BR^1, BR^2 = residue weight (mg) for duplicate blank
$B^{protein}$ = protein (mg) for blank
B^{ash} = ash (mg) for blank
B = blank weight (mg)
R^1, R^2 = residue weights (mg) of sample duplicates
$mg^{protein}$ = protein (mg) in sample residue
mg^{ash} = ash (mg) in sample residue
M^1, M^2 = weights (mg) of sample duplicates

Tannin and phytates

Tannin was determined by the method described by Pearson, (1976). Phytate was determined by the method of Latta and Eskin, (1980) as modified by Vaintraub and Lapteva (1988).

pH, total titratable acidity and Water activity (aw)

pH of a 10% (w/v) dispersion of the samples in distilled water was read with a hand held pH meter (E. Merck model). Total titratable acidity (TTA) was determined by the method of Nielsen (2002) and expressed as % lactic acid.

Water activity of instant cereal mixes were measured with a water activity analyzer, (Aqualab Model Series 3TE 08038569B Decagon Devices Inc. Pullman, Washington).

Experimental Design

The experimental design was Completely Randomized Design (CRD). The data generated from the study was subjected to analysis of variance (ANOVA) using the statistical software IBM SPSS version 20. Means were separated using Duncan Multiple Range Test (DMRT) and significance was accepted at $p < 0.05$. Values are means of triplicate determination ± standard error mean (SEM).

Results and Discussion

Selected physicochemical characteristics of dehulled millet flour, dehulled sesame meal and moringa leaf powder

Selected physicochemical characteristics of dehulled millet flour, dehulled sesame meal and moringa leaf powder (MLP) is shown in Table 2. Dehulling of the millet may have influenced the observed higher L* value (63.63), similarly lower L* value (53.73) observed in MLP may have been contributed by the presence of predominant plant pigment, chlorophyll which is naturally green in colour. Dehulled millet flour had redness value 0.97, dehulled sesame meal had 3.14 while MLP showed a greenness (-a*) value of -3.92. Greenness (-a*) value was observed in MLP, this could be attributed to the presence of chlorophyll. Higher yellowness value (19.78) observed in MLP could be attributed to ß-carotene content while lower yellowness value (11.27) observed in dehulled millet flour could be associated with dehulling of the grain.

Table 2: Selected physicochemical properties of dehulled millet, dehulled sesame meal and moringa leaf powder

Parameters	Dehulled millet	Dehulled Sesame	MLP
L*	$63.63^{a} \pm 2.02$	$59.84^{ab} \pm 0.17$	$53.73^{b} \pm 0.32$
a*	$0.97^{b} \pm 0.05$	$3.14^{a} \pm 0.01$	$-3.92^{c} \pm 0.07$
b*	$11.27^{c} \pm 0.85$	$14.66^{b} \pm 0.07$	$19.78^{a} \pm 0.21$
WAC (g/g)	$1.45^{ab} \pm 0.09$	$0.37^{b} \pm 0.02$	$2.79^{a} \pm 0.33$
SP (g/g)	$1.20^{b} \pm 0.41$	$0.60^{c} \pm 0.02$	$5.59^{a} \pm 0.03$
Moisture content %	$7.85^{a} \pm 0.06$	$1.19^{c} \pm 0.07$	$6.41^{b} \pm 0.08$
Ether extract %	$2.90^{c} \pm 0.18$	$49.85^{a} \pm 1.89$	$4.82^{b} \pm 0.41$
Total ash %	$1.33^{c} \pm 0.05$	$3.09^{b} \pm 0.01$	$8.57^{a} \pm 0.06$
Crude protein %	$7.03^{b} \pm 0.05$	$24.19^{a} \pm 0.70$	$25.33^{a} \pm 0.10$
Crude fiber %	$0.80^{c} \pm 0.01$	$4.34^{b} \pm 0.36$	$6.72^{a} \pm 0.16$
Water activity (aw)	$0.44^{a} \pm 0.00$	$0.32^{b} \pm 0.00$	$0.46^{a} \pm 0.00$
Tannins mg/100g	$1.86^{b} \pm 0.03$	$0.42^{c} \pm 0.05$	$4.06^{a} \pm 0.08$
Phytates mg/100g	$0.90^{b} \pm 0.01$	$6.48^{a} \pm 0.01$	$0.18^{c} \pm 0.03$

WAC stands for Water Absorption Capacity, SP for Swelling Powder. Means bearing the same superscript in the same row are not significantly different (p > 0.05).

Table 3. Physical properties of instant cereal mixes from graded blends of 0.75% citric acid depigmented millet, and sesame fortified with moringa leaf powder (MLP)

	Colour			Particle size distribution (µm)				Functional properties	
Sample	L*	a*	b*	Min	Mean	Max	WAC (g/g)	SP (g/g)	BD (g/cm³)
ICMQ	$77.84^{c} \pm 0.16$	$1.85^{a} \pm 0.00$	$14.42^{e} \pm 0.01$	10.16	15.44	22.35	$5.74^{b} \pm 0.18$	$6.76^{b} \pm 0.02$	$0.65^{b} \pm 0.01$
ICMA	$80.75^{a} \pm 0.13$	$1.46^{d} \pm 0.02$	$13.75^{f} \pm 0.05$	55.21	96.79	147.83	$5.70^{bc} \pm 0.03$	$7.01^{a} \pm 0.07$	$0.61^{d} \pm 0.01$
ICMB	$80.77^{a} \pm 0.03$	$1.53^{c} \pm 0.02$	$14.07^{ef} \pm 0.04$	51.96	79.51	111.49	$5.61^{bc} \pm 0.08$	$6.38^{c} \pm 0.05$	$0.62^{cd} \pm 0.00$
ICMC	$80.72^{a} \pm 0.02$	$1.40^{e} \pm 0.01$	$13.95^{f} \pm 0.02$	28.31	40.88	56.17	$5.66^{bc} \pm 0.04$	$6.24^{d} \pm 0.01$	$0.62^{cd} \pm 0.01$
ICMK	$78.18^{b} \pm 0.01$	$1.64^{b} \pm 0.01$	$15.67^{d} \pm 0.01$	36.23	52.31	75.44	$5.49^{c} \pm 0.07$	$6.42^{c} \pm 0.05$	$0.60^{d} \pm 0.00$
ICMG	$70.27^{d} \pm 0.02$	$0.32^{h} \pm 0.02$	$22.63^{c} \pm 0.35$	37.12	55.84	80.66	$5.77^{b} \pm 0.04$	$6.67^{b} \pm 0.03$	$0.63^{c} \pm 0.01$
ICMH	$67.41^{e} \pm 0.04$	$0.14^{i} \pm 0.03$	$23.72^{b} \pm 0.03$	10.35	20.26	37.29	$5.99^{a} \pm 0.03$	$6.22^{d} \pm 0.02$	$0.65^{b} \pm 0.01$
ICMI	64.60 ± 0.03	$0.03^{f} \pm 0.02$	$24.56^{a} \pm 0.03$	14.64	29.92	62.48	$4.95^{d} \pm 0.04$	$6.14^{d} \pm 0.05$	$0.69^{a} \pm 0.01$
ICMM	$64.67^{f} \pm 0.02$	0.12 ± 0.01	$24.87^{a} \pm 0.01$	26.08	40.83	74.26	$5.13^{d} \pm 0.03$	$5.36^{e} \pm 0.00$	$0.62^{cd} \pm 0.01$

WAC stands for Water Absorption Capacity, SP for Swelling Powder. Means bearing the same superscript in the same column are not significantly different (p>0.05)

LEGEND

ICMQ – 100% drum dried millet flour from dehulled millet soaked in 0.75% citric acid

ICMA – Instant cereal mix from 95% dehulled millet soaked in 0.75% citric acid + 5% dehulled sesame

ICMB - Instant cereal mix from 90% dehulled millet soaked in 0.75% citric acid + 10% dehulled sesame

ICMC - Instant cereal mix from 85% dehulled millet soaked in 0.75% citric acid + 15% dehulled sesame

ICMK - Instant cereal mix from 80% dehulled millet soaked in 0.75% citric acid + 20% dehulled sesame

ICMG - Instant cereal mix from 90% dehulled millet soaked in 0.75% citric acid + 5% dehulled sesame + 5% moringa leaf powder

ICMH - Instant cereal mix from 85% dehulled millet soaked in 0.75% citric acid + 10% dehulled sesame + 5% moringa leaf powder

ICMI - Instant cereal mix from 80% dehulled millet soaked in 0.75% citric acid + 15% dehulled sesame + 5% moringa leaf powder

ICMM - Instant cereal mix from 75% dehulled millet soaked in 0.75% citric acid + 20% dehulled sesame + 5% moringa leaf powder

Higher water absorption capacity (2.79g/g) and swelling power (5.59g/g) observed in MLP suggest the ability of MLP to retain water.

Lower moisture content was observed in dehulled sesame meal (1.19%) than in dehulled millet flour (7.85%) and MLP (6.41%). This could be attributed to the nature of seed, since it is an oilseed, having more oil content than moisture. Moisture contents of all samples were within the range (< 20%) specified by Caparino, (2002) for dried products.

The ether extract content of sesame meal was higher than that in dehulled millet flour and MLP, confirming that sesame is an oilseed, Elleuch *et al.* (2007) reported similar ether extract value (44-52%).

The total ash content of MLP was higher (8.57%) than that of dehulled millet flour and dehulled sesame meal, this value agrees with the value (7.64%) reported by Moyo *et al*. (2011) for dried moringa leaves. Lower total ash content of dehulled millet flour could be attributed to the effect of dehulling. Seghal and Kawatra (2008) reported that the removal of the outer layer of pearl millet account for mineral losses. Minerals (ash) are mostly found in the aleurone layer of grains than in the endosperm.

There was a significant difference in the crude protein content of the samples with dehulled millet flour showing low protein content of 7.03% that differed ($p < 0.05$) from that of dehulled sesame meal (24.19%) and MLP (25.33%). MLP (25.33%) and sesame (24.19%) showed comparable crude protein content. The crude fiber content of MLP was higher than that in dehulled millet flour and dehulled sesame meal. Lower crude fiber value observed in dehulled millet flour could be attributed to fiber loss due to dehulling of the grain. The water activity of dehulled millet (0.44), sesame meal (0.32) and MLP (0.46) differed significantly ($p < 0.05$) however, water activity of dehulled millet flour and MLP were comparable. Tannin content of dehulled millet was 1.86mg/100g, sesame meal was 0.42mg/100g and MLP was 4.06mg/100g. Moyo *et al.* (2011) reported that dried moringa leaves contain 30.3% protein, 3.2% tannins and 2.02% total polyphenols.

Higher phytate content (6.48mg/g) was observed in dehulled sesame meal and that compares with the phytate content (5.18%) of sesame seeds reported by Johnson *et al.* (1979). Maga, (1982) reported that defatted sesame contains highest levels of phytates found in nature compared to defatted soybean.

Physical Properties of Instant Cereal Mix From Graded Blends Of 0.75% Citric Acid Depigmented Millet, Sesame And Moringa Leaf Powder

Physical properties of instant cereal mix from graded blends of 0.75% citric acid depigmented millet, sesame and moringa leaf powder (MLP) is shown on Table 2. The inclusion of up to 15% dehulled sesame did not affect the L*values of samples ICMA (80.75), ICMB (80.77) and ICMC (80.72) however, at 20% dehulled sesame inclusion, the L* value of the sample ICMK was slightly affected (78.18). Samples ICMG (70.27), ICMH (67.41), ICMI (64.60) and ICMM (64.67) had lower L* values due probably to the influence of 5% MLP.

Samples ICMG (-0.32), ICMH (-0.14), ICMI (-0.03) and ICMM (-0.12) had negative a*-values that suggest greenness probably as influenced by inclusion of 5% MLP.

Samples ICMA had low b* value (13.75) while samples ICMI and ICMM had comparable high b* values (24.56 and 24.87, respectively).

Higher L*(whiteness), a*(redness), and b* (yellowness) values were observed in unfortified ICM compared to fortified ICM. Inclusion of 5% MLP caused significant reduction ($p < 0.05$) in the L* and whiteness index (WI) values of fortified ICM while the a* and b* values significantly increased ($p >$

0.05). Liu *et al.* (2011) similarly reported that addition of 15-45% MLP in oat flour (85, 70, and 55%) led to decreases in lightness (whiteness) and yellowness (positive b* values) and an increase in greenness (negative a* values) of extruded moringa leaf-oat flour snacks. The high b* values observed in this study could be attributed to the effect of carotenoids from MLP. Anwar *et al.* (2007) reported that moringa leaves act as a good source of natural antioxidant due to the presence of ascorbic acid, flavonoids, carotenoids and phenolics.

The minimum particle sizes of ICM indicate 10% of the flour particle sizes are less than or smaller than the diameter within the range, 10.16 - 55.21µm. The mean particle sizes imply 50% are less than 15.44 -96.79µm and 50% are greater than 15.44 -96.79µm while the maximum sizes imply 10% of ICM have particle sizes greater than 17.98 – 84.24µm.

The water absorption capacity of sample ICMH showed higher WAC, (5.99g/g) that varied significantly ($p < 0.05$) from the WAC of sample-ICMQ (5.74g/g) and other mixes (4.95 to 5.99g/g).

The variations in the swelling power of the instant cereal mixes suggest interference of sesame and MLP with the hydrophilic sites in starch molecules thus restricting the absorption of more water. Claver *et al*. (2010) attributed the swelling power of starch to the strength and character of micellar network within the starch granule, as temperature increased, the starch vibrated more vigorously breaking intermolecular bonds and allowing hydrogen bonding sites to engage more water molecules

The swelling power (5.36 to 7.01g/g) of instant cereal mixes reported in this study differs from the swelling power of raw sorghum flour (22.43g/g), 24 h soaked sorghum flour (20.01g/g), three (3) day malted sorghum flour (18.68g/g) and five (5) day malted sorghum flour reported by Claver *et al*. (2010). The level of inclusion of dehulled sesame (20%) and MLP (5%) to dehulled depigmented millet (75%) as contained in sample ICMM may have influenced the observed low swelling power (5.36g/g). Lipids and proteins in the starch granules of the samples may have formed complexes with amylose polymers and this may have inhibited the swelling of the starch in the samples (Onyango *et al.*, 2003).

Samples ICMK containing 80% dehulled depigmented millet and 20% dehulled sesame had the lowest bulk density (0.60g/cm^3) that was comparable to the bulk density of sample ICMA (0.61g/cm^3).

Chemical Composition of Instant Cereal Mixes from Graded Blends of 0.75% Citric Acid Depigmented Millet, Dehulled Sesame and Moringa Leaf Powder

The chemical composition of instant cereal mix from graded blends of 0.75% citric acid depigmented millet, sesame and moringa leaf powder (MLP) is shown in Table 4. Dehulled depigmented millet (90 to 95%) supplemented with 5 to 10% dehulled sesame (samples ICMA and ICMB) showed high moisture contents, thus reflecting the nature and extent of hydrophilic groups in the samples that readily bind water.

The ether extract, total ash, crude protein, crude fiber, phytate, tannin and total dietary fiber contents of the instant cereal mix increased with increasing level of substitution of sesame and 5% level of MLP inclusion. This could be suggestive of the nutrient value of sesame and moringa leaf powder. Inyang and Nwadimkpa (1992) reported that dehulled sesame flour contains 5.3% moisture, 55% fat, 24.3% protein, 2% crude fiber, 3% ash and 10% carbohydrate. Alobo (2001) reported that the protein, fat and ash contents of biscuits made from blends of sesame and millet in the ratio of 30:70, 40:60 and 50:50 increased significantly with increased level of sesame replacement. The biscuits made from blends of sesame and millet in the ratio of 30:70, 40:60 and 50:50 had protein contents of 19.72%, 24.91% and 30.21%, respectively and fat contents of 7.52%, 9.80% and 10.56%, respectively while the ash contents were 2.48%, 2.53% and 2.90%, respectively.

Liu *et al.* (2011) reported that the crude fiber and protein contents of extruded snacks made from blends of oat flour and MLP in the ratios of 100:0, 85:15, 70:30 and 55:45 improved significantly with increased level of moringa inclusion. The protein content of extruded snacks made from blends of oat flour and moringa leaf powder in the ratios of 100:0, 85:15, 70:30 and 55:45 were 8.25%, 10.40%, 12.57% and 13.66%, respectively while the fiber contents were 0.82%, 1.88%, 2.98% and 4.19%, respectively. A similar trend was observed in this study, protein and fiber contents increased with increase in sesame substitution and with the inclusion of 5% MLP.

The mix (ICMQ) that contained 100% millet had the lowest total ash content (0.68%), the total ash content of dehulled sesame (3.09%) and MLP (8.57%) may have influenced the total ash contents of the instant cereal mixes.

Sample ICMM showed higher crude protein content (12.74%) that varied significantly ($p < 0.05$) from the control (8.05%) and other mixes (9.91% in sample ICMA to 11.31% in sample ICMI). However, samples ICMB and ICMG had comparable crude protein contents of 10.12% and 10.32%, respectively. The crude protein contents of sesame (24.19%) and MLP (25.33%) may have influenced the crude protein contents of the instant cereal mixes.

Blending 0.75% citric acid depigmented dehulled millet with sesame at different levels (0, 5, 10, 15 and 20%) and inclusion of 5% MLP increased tannin and phytate contents suggesting that the residual contents of tannin and phytate present in sesame and MLP may have influenced tannin increase in the mixes. Maga, (1982) reported that sesame seeds contain highest levels (5.18%) of phytate found in nature while defatted sesame contains more phytic acid than defatted soybean (Johnson *et al.*,1979). Moyo *et al.* (2011) reported that dried moringa leaves contain 30.3% protein, 3.2% tannins and 2.02% total polyphenols.

Sample ICMM showed higher total dietary fiber content (16.44%) that varied significantly ($p < 0.05$) from total dietary fiber content of ICMQ (6.26%) and other ICM (9.23 to 16.44%). However, samples ICMA, ICMB and ICMK had comparable total dietary fiber contents of 9.23%, 9.50% and 9.55%, respectively. Elleuch *et al.* (2007) reported that sesame seeds and its products had insoluble dietary fiber content that range from 13.96 to 33.41% while the level of soluble dietary fiber range from 0.4 to 4.1%, and total dietary fiber ranged from 19.33 to 42.03%. Moringa leaf powder was reported to contain 27.1% protein and 19.2% total dietary fiber (Liu *et al.*, 2011; Fugile, 2001). Even though, higher contents of total dietary fiber were reported for millet, sesame and moringa leaf powder, pretreatments such as dehulling of millet and sesame may have caused the reduction of total dietary fiber contents of these samples used in the present study.

Amino acid profile of instant cereal mix made from graded blends of 0.75% citric acid depigmented millet, sesame and moringa leaf powder.

Amino acid profile of instant cereal mix from graded blends of 0.75% citric acid depigmented millet, dehulled sesame and moringa leaf powder (MLP) is shown in Table 5. The essential amino acid profile of instant cereal mixes was compared with the FAO reference (FAO, 1991) stipulated for an egg.

Table 4: Chemical composition of instant cereal mix from graded blends of 0.75% dehulled citric acid depigmented millet, dehullled sesame and MLP

	ICMQ	ICMA	ICMB	ICMC	ICMK	ICMG	ICMH	ICMI	ICMM
MC (%)	_ $^{c}\pm0.18$	$6.52^{a}\pm0.07$	$6.48^{a}\pm0.04$	$5.96^{d}\pm0.08$	$4.64^{d}\pm0.16$	$6.03^{b}\pm0.16$	$6.05^{b}\pm0.15$	$5.53^{c}\pm0.17$	$4.62^{d}\pm0.11$
EE (%)	$2.73^{g}\pm0.16$	$5.98^{ef}\pm0.04$	$8.82^{d}\pm0.31$	$10.94^{b}\pm0.25$	$12.36^{a}\pm0.19$	$4.98^{f}\pm0.05$	$6.82^{e}\pm0.56$	$9.77^{cd}\pm0.83$	$11.81^{ab}\pm0.08$
TAsh(%)	$0.68^{f}\pm0.12$	$0.93^{e}\pm0.00$	$0.99^{de}\pm0.06$	$1.15^{cde}\pm0.04$	$1.20^{cd}\pm0.11$	$1.31^{bc}\pm0.04$	$1.46^{b}\pm0.03$	$1.71^{a}\pm0.04$	$1.75^{a}\pm0.11$
CP (%)	$8.05^{f}\pm0.33$	$9.91^{e}\pm0.19$	$10.12^{de}\pm0.25$	$10.46^{cde}\pm0.17$	$10.69^{cd}\pm0.17$	$10.32^{de}\pm0.09$	$11.02^{bc}\pm0.23$	$11.31^{b}\pm0.12$	$12.74^{a}\pm0.06$
Cf (%)	$0.76^{f}\pm0.06$	$0.94^{e}\pm0.03$	$1.02^{e}\pm0.05$	$1.16^{d}\pm0.03$	$1.16^{d}\pm0.00$	$1.30^{c}\pm0.02$	$1.41^{b}\pm0.03$	$1.47^{ab}\pm0.01$	$1.52^{a}\pm0.02$
pH	$4.88^{h}\pm0.01$	$5.08^{f}\pm0.01$	$5.16^{e}\pm0.00$	$5.31^{c}\pm0.00$	$5.56^{a}\pm0.00$	$5.01^{g}\pm0.01$	$5.15^{e}\pm0.01$	$5.21^{d}\pm0.01$	$5.51^{b}\pm0.00$
*TTA	$0.10^{ab}\pm0.01$	$0.08^{c}\pm0.00$	$0.09^{bc}\pm0.00$	$0.09^{bc}\pm0.00$	$0.09^{bc}\pm0.00$	$0.11^{a}\pm0.00$	$0.09^{bc}\pm0.00$	$0.06^{e}\pm0.00$	$0.06^{e}\pm0.00$
aw	$0.52^{a}\pm0.00$	$0.34^{e}\pm0.00$	$0.35^{d}\pm0.00$	$0.37^{c}\pm0.00$	$0.31^{f}\pm0.00$	$0.38^{b}\pm0.00$	$0.38^{b}\pm0.00$	$0.38^{b}\pm0.00$	$0.34^{e}\pm0.00$
*Phytates	$0.30^{h}\pm0.03$	$0.55^{g}\pm0.01$	$0.83^{f}\pm0.02$	$1.08^{e}\pm0.02$	$1.25^{d}\pm0.03$	$1.09^{e}\pm0.01$	$1.56^{c}\pm0.01$	$1.75^{b}\pm0.02$	$1.97^{a}\pm0.01$
*Tannins	$1.00^{e}\pm0.02$	$1.03^{d}\pm0.00$	$1.02^{d}\pm0.00$	$1.16^{c}\pm0.01$	$1.16^{c}\pm0.00$	$1.45^{b}\pm0.05$	$1.37^{c}\pm0.08$	$1.50^{a}\pm0.09$	$1.42^{b}\pm0.06$
TDF (%)	$6.26^{e}\pm1.17$	$9.23^{d}\pm0.57$	$9.50^{d}\pm0.13$	$11.19^{cd}\pm0.27$	$9.55^{d}\pm0.70$	$12.23^{c}\pm0.33$	$13.15^{bc}\pm0.62$	$14.65^{ab}\pm0.27$	$16.44^{a}\pm0.89$

Means bearing the same superscript in the same column are not significantly different ($p>0.05$)

*measured in mg/100g. MC stands for Moisture content, EE for ether extract, TAsh for Total ash, CP for Crude Protein, Cf for Crude fibre, TTA for total titratable acidity, aw for water activity and TDF for Total dietary fiber.

LEGEND

ICMQ – 100% drum dried millet flour from dehulled millet soaked in 0.75% citric acid
ICMA – Instant cereal mix from 95% dehulled millet soaked in 0.75% citric acid + 5% dehulled sesame
ICMB - Instant cereal mix from 90% dehulled millet soaked in 0.75% citric acid + 10% dehulled sesame
ICMC - Instant cereal mix from 85% dehulled millet soaked in 0.75% citric acid + 15% dehulled sesame
ICMK - Instant cereal mix from 80% dehulled millet soaked in 0.75% citric acid + 20% dehulled sesame
ICMG - Instant cereal mix from 90% dehulled millet soaked in 0.75% citric acid + 5% dehulled sesame + 5% MLP
ICMH - Instant cereal mix from 85% dehulled millet soaked in 0.75% citric acid + 10% dehulled sesame + 5% MLP
ICMI - Instant cereal mix from 80% dehulled millet soaked in 0.75% citric acid + 15% dehulled sesame + 5% MLP
ICMM - Instant cereal mix from 75% dehulled millet soaked in 0.75% citric acid + 20% dehulled sesame + 5% MLP

Table 5: Amino acid profile (mg/g) of instant cereal mix from graded blends of 0.75% citric acid depigmented millet, sesame and moringa leaf powder (MLP)

Amino acid	SAMPLES									FAO Reference (mg/16g N)
	ICMQ	ICMA	ICMB	ICMC	ICMK	ICMG	ICMH	ICMI	ICMM	
His	6.99	8.50	9.22	9.93	10.13	10.47	10.28	11.58	11.88	22
Thr	5.23	5.93	6.94	8.07	7.53	5.96	7.84	9.46	9.50	47
Phe + Tyr	17.87	19.71	27.89	25.39	26.49	21.38	26.24	28.55	29.85	93
Met + Cys	4.58	8.84	10.24	11.51	12.78	8.04	8.92	12.19	13.11	53
Val	5.21	5.74	5.69	5.19	6.06	6.08	7.05	7.56	7.57	66
Ile	6.06	6.51	6.41	6.59	7.02	6.02	7.83	8.01	8.46	54
Leu	6.05	7.74	6.78	6.95	7.16	6.81`	7.84	8.26	8.25	86
Lys	2.36	3.05	6.38	8.26	8.16	8.28	11.39	11.00	11.46	70

LEGEND

ICMQ – 100% drum dried millet flour from dehulled millet soaked in 0.75% citric acid
ICMA – Instant cereal mix from 95% dehulled millet soaked in 0.75% citric acid + 5% dehulled sesame
ICMB - Instant cereal mix from 90% dehulled millet soaked in 0.75% citric acid + 10% dehulled sesame
ICMC - Instant cereal mix from 85% dehulled millet soaked in 0.75% citric acid + 15% dehulled sesame
ICMK - Instant cereal mix from 80% dehulled millet soaked in 0.75% citric acid + 20% dehulled sesame
ICMG - Instant cereal mix from 90% dehulled millet soaked in 0.75% citric acid + 5% dehulled sesame + 5% moringa leaf powder
ICMH - Instant cereal mix from 85% dehulled millet soaked in 0.75% citric acid + 10% dehulled sesame + 5% moringa leaf powder
ICMI - Instant cereal mix from 80% dehulled millet soaked in 0.75% citric acid + 15% dehulled sesame + 5% moringa leaf powder
ICMM - Instant cereal mix from 75% dehulled millet soaked in 0.75% citric acid + 20% dehulled sesame + 5% moringa leaf powder

The fICM showed the highest concentration of all amino acid followed by uICM, the control sample ICMQ had amino acid profile with the lowest amino acid concentration.

Moringa has been reported to contain high quality and easily digestible protein, therefore the observed high concentration of amino acid in the amino acid profile of samples ICMI and ICMM may be a reflection of the combined influence of moringa and sesame on the amino acid profile of the mixes.

Conclusion and Recommendation

Drum drying technology can be used for the production of RTE (instantized) breakfast food products made from blends of millet seeds, sesame seeds and moringa leaves.

Nutritional quality of millet can be improved with the inclusion of sesame and moringa.

Fortified instant cereal mix (blends of dehulled 0.75% citric acid depigmented millet, dehulled sesame and 5% MLP) showed higher concentration of amino acids, crude protein, total ash, total dietary fiber and mineral contents than control sample (100% dehulled 0.75% citric acid depigmented millet).

Unfortified instant cereal mixes (blends of dehulled 0.75% citric acid depigmented millet and dehulled sesame) showed higher L*-whiteness values than fortified mixes (blends of dehulled 0.75% citric acid depigmented millet, dehulled sesame and 5% MLP). Inclusion of MLP influenced the negative a* value (greenness) and yellowness (b*) values.

Acceptable breakfast products can be produced using depigmented dehulled millet complemented with dehulled sesame up to 20%. Further studies may require understanding the invitro digestibility of the ICM.

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