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Full Length Research Paper

The dehulling efficiency and physicochemical properties of pre-conditioned mungbean (*vigna radiata* (l). wilczek) seeds and flour

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Abstract

Mungbean (*Vigna radiata* (L.) Wilczek) seeds (400g) were each subjected to different pre-conditioning treatments (soaking, boiling and toasting) to evaluate their effect on dehulling efficiencies. They were dried, milled into flour and the effect of pre-conditioning treatments on their proximate composition and functional properties were determined. The samples were also used to produce cakes. Results showed that toasting was the least efficient method of dehulling, having the least dehulling percentages of 32.68% and 36.00% for 45 min and 60 min toasted samples respectively. Samples soaked in boiled water for 45 min were the most efficiently dehulled (52.64η) dehulling efficiency, followed by samples soaked in cold water for 8h and 12h (49.92η and 49.82η) dehulling efficiencies respectively which did not significantly differ (p<0.05) from the dehulling efficiency of samples soaked with sodium bicarbonate (43.68η). Toasted samples (45min and 60min) had the least protein content (22.64% and 22.81 %) and differed significantly at p<0.05 from others. Significant differences (P<0.05) existed among the functional properties of samples, especially oil absorption capacity, foam capacity, bulk density and emulsion capacity. The cakes produced from 10% mungbean: 90% wheat flour gave the best sensory characteristics when compared with the cake sample from 20% substitution with mung bean flour.

Keywords: Mung beans, pre-conditioning, dehulling, soaking, toasting, cake.

INTRODUCTION

Mungbean (Vigna radiata (L) wilczek, Syn. Phaseoulus aureus proxb, P. mungo. P. radiatus L) also known as green bean, mung, mongo, moongo, moon dal (in Bengali), mushbean, munggo or monggo, green grain, golden grain and green soy originated from south east Asia (India) and has been mostly grown in Asian countries like Thailand, Burma, Indonesia and Philippines. It is now widely cultivated in Africa, South America, Australia and the United States (Kim *et al.*, 2007).

About 90% of the world production of mungbean (*Vigna radiata* .L.) is produced in Indo Burma region. Mungbeans are tropical (or sub tropical) crops and require warm temperature (optimally around 30-35^{o}C,) loamy soil is best for its cultivation (Opoku *et al.,* 2003).

Mungbean as one of the pulses is a rich source of protein for animal and human consumption; it supplies a significant amount of minerals and vitamins. Typically, the average nutritional composition of mungbean is 22.9% protein, 61.8% carbohydrate, 1.2% fat, 4.4% fiber and 3.5% ash (Duke, 1981). Mungbean may consist of 12.1% seed coat, 2.3% embryo ad 85.6% cotyledlons (Singh *et al.,* 1968). Mungbean is an excellent and cheap source of protein and calcium and is well suited for cultivation throughout the tropics and sub tropics. It has attributes that suggest it could thrive in the South Eastern Nigeria (Agugo, 2003), and also be a better nutritional supplement to enhance diet as it supplies essential plant protein, vitamin and minerals (Chen, 1990).

The seed colour is usually dark olive green, bright green skin or yellow and the beans are small, cylindrical or ovoid, globular or oblong in shape, but some cultivars produce brown or speckled black seed (Kay, 1979; Rubatzky and Yamaguchi, 1997; Anonymous 2008).

The International Institute for Tropical Agriculture (IITA) Ibadan Nigeria have some genotypes of mungbean and efforts are being made to increase the production of the mungbean seeds (Mensah and Olukoya, 2007). Mungbean seeds were also recently introduced into the mid-western Nigeria to supplement the dietary requirements of the indigenous communities and the performance of the phenotypic character of mungbean (*Vigna mungo* (L) Hepper), genotypes grown at Ekpoma in Edo state were evaluated and from the yield and yield attributes of the three genotypes – TVM1, TVMI1 and TVMI5 was found to be most suitable for the Esan Plateau of the mid-western Nigeria (Mensah and Okukoya, 2007; Akaerue and Onwuka, 2010).

Mungbean is not very popular, especially in most part of Nigeria, however, a food could be popularized and made to become more useful to the body by the culinary proficiency of the producer or by diversifying its uses. However, Agugo and Onimawo, (2008) reported that mungbean has gained popularity to an extent in many parts of the country including southern and eastern Nigeria. Mungbean can be consumed as hulled, splits, whole, canned, boiled, roasted or ground into flour to make a variety of deserts, snacks and main dishes in most part of the world including Nigeria (Anonymous, 2010). Mung beans are cooked with sugar, coconut milk and a little ginger. It has also been reported to have several medicinal uses (Leung, 2007; Akaerue and Onwuka, 2010).

The main purpose of preconditioning is to loosen the hull and facilitate its separation from the kernel thereby reducing dehulling losses (Opoku *et al.,* 2003). The problem of hard- to cook and hard to dehull syndrome have made the utilization of mung beans less interesting because it is time consuming and energy demanding. The difficulty in dehulling could be contributed by its small size and the mucilage between the kernel and the seed coat. The variability in dehulling characteristics of legume grains may be affected by grain genotypes and their physical characteristics. Dehulling characteristics of mungbean is certainly one of the primary traits which may be considered by breeders. Legumes with good dehulling characteristics are required by processors to satisfy both domestic and the export markets (Opoku *et al.*, 2003).

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Moreover, the knowledge of and ability to harness the effect of the preconditioning treatments on dehulling efficiency of mungbean seed can equally help widen its uses.

Dehulling mungbean helps to remove anti nutritional factors located in the seed coats, improves cooking and nutritional qualities and as well reduces cooking time and improve the digestibility (Deshpande *et al.,* 1982). Dehulling characteristics of mungbean is certainly one of the primary traits which may be considered by breeders. Legumes with good dehulling characteristics are required by processors to satisfy both domestic and the export markets (Opoku *et al.*, 2003).

Pre-conditioning method to loosen the hulls may involve heat treatment alone or soaking in water or chemical solution for a period of time, together with heat treatment followed by hot dehulling or tempering before dehulling. Kernel preconditioning is generally designed to toughen the hull and loosen the gummy bond between the hull and cotyledon and to harden the cotyledon to reduce damage (Opoku *et al.*, 2003).

Therefore, the aim of this investigation was to identify and evaluate the effect of preconditioning operations on the dehulling efficiency and the physicochemical properties of mungbean seeds and the resulting flour, as well as the quality of cake produced with flours.

MATERIALS AND METHODS

The mungbean seeds were obtained from the College of Crop and Soil Sciences (CCSS), Department of Crop Science, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Laboratory facilities and the analytical grade reagents used for the study were obtained from the department of Food Science and Technology (FST) laboratory and the National Root Crops Research Institute (N R C R I) Umudike. The ingredients used for the cake production were purchased from Umuahia main market, Abia State, Nigeria.

Sample preparation

The mungbean seeds were cleaned, weighed with electronic balance and divided into four major portions. The first portion was sub-divided into two (400g each) and soaked in cold water (1:3 w/v) for 8 h and 12 h respectively. The second portion (400g) was soaked with 5% sodium bicarbonate solution (1:3 w/v) for 30 min, the third portion (400g) was soaked in boiled water (1:3 w/v) for 45 min and the fourth portion was then subdivided into two sets of 400g each and were toasted at 100^{o}C for 60 min and 45 min at 120^{o}C respectively.

The samples were then oven dried (65^{o}C), after the pre-conditioning treatments and then dehulled abrasively and winnowed to separate the hulls form the cotyledons (figure1).

The dehulled samples were separated manually into different fractions such as whole and split dehulled kernels, undehulled kernels, fines and hulls.

A kernel was considered completely dehulled when there was no hull adhering to it or about 90% hulls had been removed, (Opoku *et al.,* 2003) with minor modifications and the analyses were carried out in duplicates.

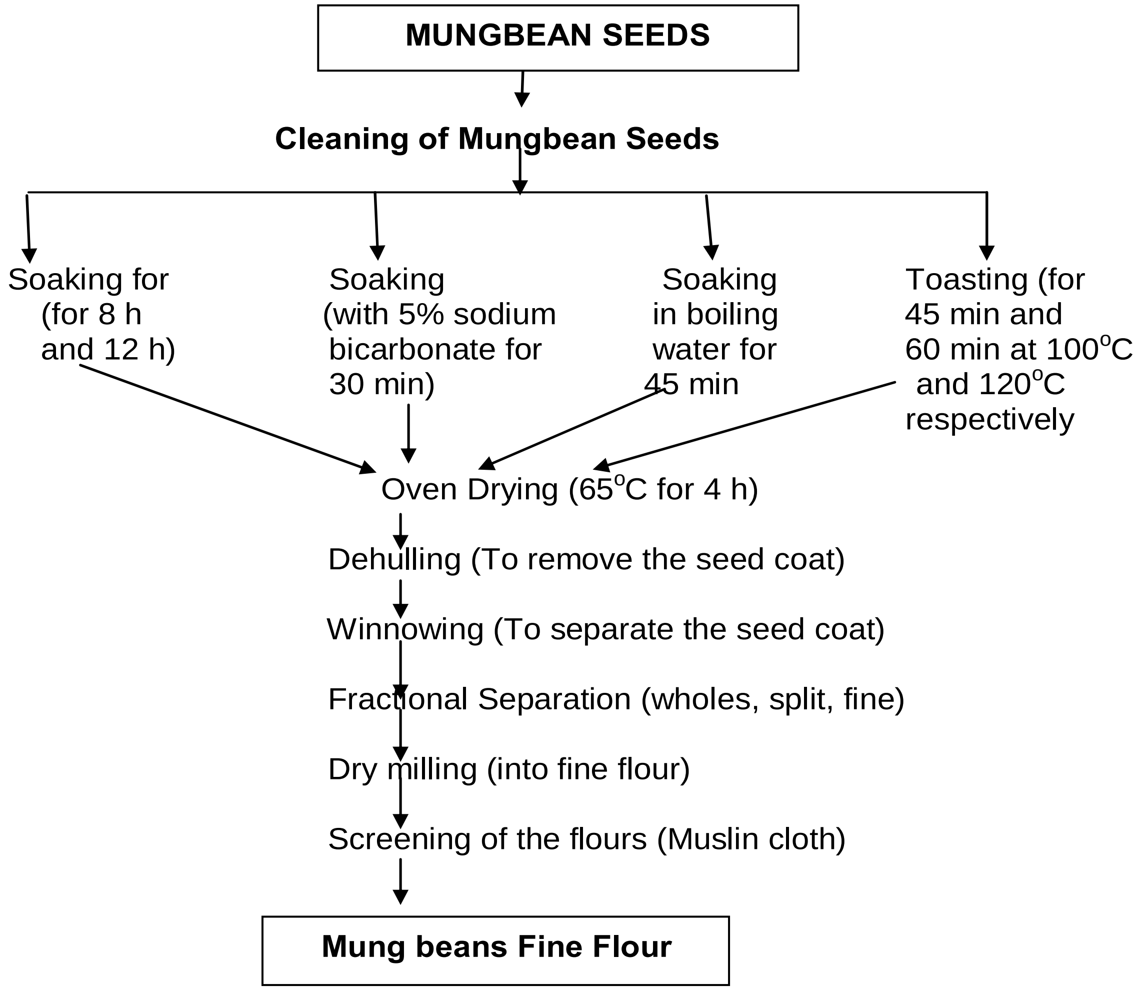

Figure 1. Flow Chart showing the conversion of mungbean seeds into flours

Dehulling efficiency determinations

The Dehulling Index (η)

This was calculated using the method described by Opoku *et al.(* 2003).

$$\eta = \frac{(mk + mh) - mud + mh)}{mi}$$

where: mk = mass of dehulled kernel (whole and split) (g).

mh = mass of hull (g)
mud = mass of fine fraction (g)
mi = Initial mass of sample taken for dehulling (g).

Degree of Dehulling (Mh)

The degree of dehulling is the ratio of mass of hull removed during dehulling to the initial mass of sample used for the dehulling process.

Effectiveness of dehulling (Ed)

This is the ratio between the mass of the material remaining undehulled and the initial mass of sample taken for dehulling

Yield of Fine (Yf)

This is the ratio between the mass of fine generated during dehulling and the initial mass of sample.

Coefficient of dehulling (cdh) was calculated from the expressions:

Cdh = 100 [I – (Yf – Ed] - - - (2)

Overall dehulling efficiency (**η**o)

ηo = (Mh + Qd) x cdh - - - - (3)

where: Qd = quality of dehulling can be calculated as the ratio between the weight of dehulled kernel (both split and whole) and initial weight of sample.

Table 1. Preconditioning Methods Employed

Treatments	Description
A. Soaking and drying	A1: Soaking for 8 h and drying at 65^oC for 4 h A2: Soaking for 12 h and drying at 65^oC for 4 h.
B. 5% Sodium bicarbonate soaking and drying	Soaked for 30 min and dried at 65^oC for 4 h.
C. Hot water soaking and drying	Soaked in boiling water (100^oC) for 45 min, drying at 65^oC for 4 h.
D. Toasting	D1: Toasted at 100^oC for 60 min. D2: Toasted at 120^oC for 45 min.

After determining the dehulling efficiency, the samples were then milled, sieved and packaged for analysis.

Proximate Analysis of the Flour Samples

The moisture content and crude protein was determined by the gravimetric method while the Nitrogen free Extract (NFE) was calculated as the carbohydrate content (AOAC, 1990). The crude fat and ash were determined by the method of James (1995). The Weende Method described by Pearson (1976) was used for crude fibre determination.

Functional Properties Determination

The water absorption capacity, gelatinization temperature, and emulsifying activity were determined by the method of Onimawo and Egbekun (1988). The oil absorption capacity was determined by method of Sosulski et al. (1976). The method of Narayana and Narasinya – Rao, (1982) was adopted for foam capacity and stability. For wettability, the method of Armstrong *et al.* (1979) was adopted.

Cake Production

The mungbean flour samples obtained were used in cake production and IFIS (2005) method was adopted; where butter and sugar were creamed together, thereafter other ingredients such as egg, salt, baking powder and floor were added. Each of the mungbean flour samples was blended and mixed thoroughly with wheat flour in an electric mixer and the production was carried out in two batches. In batch one, 10% of mungbean flour and 90% of wheat flour was used for each sample while in the second batch 20% of mungbean flour and 80% of wheat flour was also used for each sample.

The proportions of the ingredients used were as follows:

Ingredients	Quantity
Margerine	½ teaspoon for each sample
Sugar	½ teaFspoon ”
Flour	100g ”
Baking powder	1 g ”
Salt	0.1g ”
Water	1½ cup ”

The dough was gradually put into the baking pans and baked at 190^oC for 30 min.

Organoleptic Evaluation of the Cakes Produced From Mungbean

The sensory evaluation of the cake samples was carried out with 20 panelists and the 9 point hedonic scale was used, with 9 and 1 rating dislike extremely and like extremely respectively. The panelists were asked to identify the differences in texture, colour, aroma, taste and general acceptability and comment appropriately. The samples were coded to avoid bias. The codes were:

Codes	Meaning
601	Samples soaked for 12 h
602	Samples soaked for 8 h
603	Samples soaked with sodium bicarbonate for 30 min
604	Samples soaked in boiled water for 45 min.

Table 2. Mean values for some Dehulling Efficiency Indicators of Mungbean Seeds given Different Pre-Conditioning Treatments

Treatment	Whole Dehulled Kernels %	Split Dehulled kernels %	Effectiveness of dehulling (Ed) %	Degree of dehulling (Mh) %	Yield of fines (Yf) %	Dehulling index (**η**)	Coefficient of dehulling (Cdh) %	Overall dehulling efficiency (**η**)	Quality of dehulling (Qd)
Sample soaked in cold water for 8 h	$25.00^{a} \pm 0.02$	$16.25^{b} \pm 0.04$	$2.00^{d} \pm 0.01$	$8.00^{b} \pm 0.03$	$4.00^{ab} \pm 0.01$	$0.57^{a} \pm 0.04$	$23.50^{a} \pm 0.02$	48.82^{b} 0.32	$0.45^{a} \pm 0.01$
Sample soaked in cold water for 12 h	$26.40^{a} \pm 0.03$	$15.00^{b} \pm 0.05$	$1.93^{d} \pm 0.00$	$5.00^{c} \pm 0.01$	$2.35^{b} \pm 0.01$	$0.47^{ab} \pm 0.10$	$24.00^{a} \pm 0.02$	$49.59^{b} \pm 0.00$	$0.44^{ab} \pm 0.01$
Samples soaked with sodium bicarbonate	$21.67^{ab} \pm 0.00$	$12.50^{c} \pm 0.05$	$4.00^{b} \pm 0.01$	$5.00^{c} \pm 0.03$	$5.00^{a} \pm 0.00$	$0.38^{b} \pm 0.01$	$22.75^{a} \pm 0.02$	$43.68^{c} \pm 0.05$	$0.43^{bc} \pm 0.01$
Samples soaked in boiled water for 45 min.	$13.83^{c} \pm 0.02$	$24.78^{a} \pm 0.05$	$2.00^{d} \pm 0.01$	$14.00^{a} \pm 0.00$	$4.00^{ab} \pm 0.05$	$0.51^{ab} \pm 0.06$	$23.50^{a} \pm 0.03$	$52.64^{a} \pm 0.00$	$0.42^{c} \pm 0.01$
Samples toasted for 45 min	$20.15^{ab} \pm 0.02$	$12.35^{c} \pm 0.03$	$19.00^{a} \pm 0.06$	$5.00^{c} \pm 0.01$	$5.00^{a} \pm 0.01$	$0.19^{c} \pm 0.02$	$19.00^{b} \pm 0.32$	$32.68^{e} \pm 0.00$	$0.38^{e} \pm 0.01$
Samples toasted for 60 min	$17.00^{bc} \pm 0.06$	$15.00^{b} \pm 0.03$	$15.00^{b} \pm 0.02$	$3.00^{b} \pm 0.04$	$5.00^{b} \pm 0.04$	$0.25^{c} \pm 0.05$	$20.00^{b} \pm 0.01$	$36.00^{d} \pm 0.02$	$0.40^{d} \pm 0.01$

a b c d e means with different superscripts along a column are significantly different (P<0.05)
Values are mean ± standard deviation of three replications.

605 Samples toasted for 45 min at 120°C
606 Samples toasted for 60 min at 100°C.

Second Batch

Mungbean (20%): Wheat flour (80%)

Codes	**Meaning**
701	Samples soaked for 12 h
702	Samples soaked for 8 h
703	Samples soaked with sodium bicarbonate for 30 min
704	Samples soaked in boiled water for 45 min
705	Samples toasted for 45 min at 120°C
706	Samples toasted for 60 min at 110°C.

12 Samples were used in the sensory evaluation.

Statistical analysis of data

The experimental design used in this work was a Complete Randomized Design (CRD) and the data was subjected to analysis of variance (ANOVA) to determine the significant difference using Duncan – Multiple Range Test (SPSS, 1999).

Table 3. Proximate Composition of the Pre-conditioned Dehulled Mungbean Flour Samples

Samples	Moisture (%)	Dry matter (%)	Ash (%)	Protein (%)	Fat (%)	Crude Fibre (%)	Carbohydrate (%)
Control (raw)	10.14^{c}± 0.03	89.86^{b}± 0.03	3.73^{a} ± 0.02	27.93^{a} ± 0.04	1.93^{a} ± 0.01	4.58^{a}±0.00	51.50^{f} ± 0.32
Soaked for 8h	10.56^{b}± 0.03	89.44^{c}± 0.03	3.72^{a} ± 0.00	27.81^{b} ± 0.01	1.86^{b} ± 0.01	4.52^{b}±0.00	51.54^{ef} ± 0.04
Soaked for 12h	10.82^{a}± 0.02	89.45^{c}± 0.35	3.68^{b} ± 0.01	27.32^{c} ± 0.05	1.83^{c} ± 0.01	4.50^{b}±0.01	51.87^{c} ± 0.04
Soaked in Na_2CO_3	10.22^{c}± 0.05	89.79^{b}± 0.05	3.62^{d} ± 0.00	26.28^{d} ± 0.04	1.80^{d} ± 0.00	4.44^{c}±0.01	53.65^{d} ± 0.10
Toasted for 45 min	9.31^{d} ± 0.10	90.69^{a}± 0.10	3.58^{e} ± 0.00	22.81^{f} ± 0.01	1.65^{c} ± 0.01	3.81^{d}±0.02	58.85b ± 0.15
Toasted for 60 min	9.24^{d} ± 0.06	90.76^{a}± 0.06	3.53^{f} ± 0.01	22.64^{g} ± 0.01	1.61^{f} ± 0.01	3.67^{c}±0.02	59.32^{a} ± 0.06
Boiled for 45 min	10.25^{c}± 0.01	89.75^{bc}±0.01	3.65^{c} ± 0.00	25.73^{c} ± 0.04	1.86^{b} ± 0.01	4.52^{b}± 000	54.00^{c} ± 0.05

a b c d e f g means with different superscripts along a column are significantly different (P <0.05)
Values are mean ± standard deviation of two replications.

RESULTS AND DISCUSION

Dehulling Efficiency Indicators of Mungbeans Given Different Pre-conditioning Treatments

The mean results of the dehulling efficiency indicators of mungbean seeds with various pre-conditioning treatments were shown in Table 2. There were significant differences (P<0.05) among the dehulling efficiencies of the pre-conditioned mung bean seeds.

The percentage of whole dehulled kernels were higher and differed significantly (P<0.05) from the split dehulled kernels in all the treatments. Soaked samples had the highest whole dehulled kernels (25.00% and 26.40%) for 8 h and 12 h respectively. Samples soaked in boiled water had the least whole dehulled kernels (13.83%) and the highest split dehulled kernels (24.78%). This implied that soaking mungbean seeds between 8 to 12 h produced reasonable quantities of whole dehulled kernel compared to other treatments, and soaking in boiled water for 45 min produced reasonable quantities of split dehulled kernels. Samples toasted for 45 min (120^{o}C) produced higher undehulled kernels (19.00%) and lowest dehulling efficiency (32.68 **η**o) which differed significantly (P<0.05) from others. Samples soaked with 5% sodium bicarbonate gave an overall dehulling efficiency of 43.68 **η**o. Toasted samples had the lowest fines. Samples soaked in boiled water for 45 min differed significantly (P<0.05) in their whole (13.83%) and split (24.78%) dehulled kernels respectively, with the highest hull, dehulling index and overall dehulling efficiency of 14.00%, 0.51**η** and 52.64 **η**o respectively.

Samples soaked in cold water had 48.82 **η**o and 49.59 **η**o overall dehulling efficiency for 8 h and 12 h soaking respectively. Compared to all the pre-conditioning treatments, samples toasted for 45 min (120^{o}C) gave the lowest overall dehulling efficiency (32.68 **η**o) followed by 60 min toasted samples (100^{o}C) which gave 36.00 **η**o as its overall dehulling efficiency. The ones soaked with 5% sodium bicarbonate gave the lowest split dehulled kernels. Samples soaked in boiled water produced a better result compared to the other treatments and differed significantly (P<0.05) followed by the samples soaked for 12 h, 8 h and with sodium bicarbonate respectively. The toasted samples gave the lowest dehulling efficiencies since their percentage undehulled kernels were higher and their overall dehulling efficiencies were significantly lower compared to the other treatments.

The result showed that the pre-conditioning treatment was necessary to obtain reasonable percentage of dehulled mungbean kernel, good dehulling index as well as overall dehulling efficiency. So generally, the wet treated samples (boiled and soaked) produced the best dehulling efficiency than the dry heat treated samples (toasting).

Proximate Composition of the Pre-conditioned Mungbean Flour Samples

As shown in Table 3, the moisture contents of the raw and toasted mungbean flour samples differed significantly (P<0.05) while boiled and the sample soaked with sodium bicarbonate showed no significant differences (P >0.05) among them. The samples soaked for 8 and 12 h showed slight differences between them.

The control (raw) mung bean flour, had a moisture content of 10.14% which agreed with the report of Agugo and Onimawo (2008), which indicated that mungbean flour had moisture content of 9.30%. The moisture content of the mungbean flour was observed to qualify for the standard expected of dry legumes (10.14%) as reported by USDA (1999; Belderok *et al.,* 2000). The boiled samples showed no significant difference (p>0.05) with the raw mungbean flour. Mubarak (2005) also reported that boiling had no significant effect (p>0.05) on the moisture content of dehulled mungbean flour (10.25%). There were no significant difference (P>0.05) between the moisture content of the dehulled mungbean flour toasted for 45 min and 60 min with the values 9.31% and 9.24% respectively.

However, toasting treatment being a dry heating method reduced the moisture content of the flour significantly (P< 0.05) when compared with the raw flour (10.14%). This could be due to the high temperature of toasting (100^{o}C – 120^{o}C) and prolonged time, 60 min and 45 min respectively.

The protein content of the raw mungbean flour was 27.93% which fell within the range observed by other researchers. According to the findings of other researchers, mungbean seed flour had protein content of 20 – 27% (Thompson, 1977); 22.9% (Duke, 1981); 27.6% (Mubarak, 2005); 25.09% (Agugo and Onimawo, 2007) and 28.38% (Akaerue and Onwuka, 2010). All these reports had shown that dehulled mungbean seed flours contain protein which was higher than or equal to some of the well known and commonly consumed legumes such as bambara groundnut, (18 – 20.73%), Cowpea (22%), Peanut (24.3 – 27%) (Muller, 1988); Sosulski (1983); Akinjayeju and Francis (2007).

However, the protein content of dehulled mungbean seed flour were lower than that of soy bean (55.56%) (Sosulki *et al.,* 1976); 45.3 – 46.8% (Ukwuru, 2003). There were significant differences (P< 0.05) among the protein content of the raw and processed samples. Soaking and boiling decreased the protein content with increasing time (27.81%, 27.32%, 26.28% and 25.73%) for samples soaked for 8 h, 12 h, with sodium bicarbonate and samples soaked in boiled water for 45 min respectively. Toasting reduced the protein content of mungbean to 22.81% and 22.64% for samples toasted for 45 min and 60 min respectively. This may be as a result of the high temperature used.

The raw crude fat content of the mungbean flour (1.93%) significantly differed (p<0.05) from the fat content of pre-conditioned mungbean flours. The fat content of samples soaked for 12h, 8 h and in boiled water were 1.38%, 1.86% and 1.86% respectively which agreed with the result of Mubarak (2005), who reported that the fat content of mungbean seed were 1.82%. Agugo and Onimawo (2008) showed that all the raw mungbean contained 1.45%. Toasting reduced the fat content significantly (P<0.05) to 1.65% and 1.61% for 45 min and 60 min toasting respectively. Agugo and Onimawo (2008) also reported a reduction in the fat content of toasted mungbean seed flour.

The crude fibre of raw mungbean seed flour was found to be 4.58% which approached the crude fibre content reported by Mubarak (2005), (4.10%). Soaked samples (8h and 12h) and boiled samples were not significantly different (P>0.05) in their fibre content. The sample soaked with 5% sodium bicarbonate showed significant difference (P<0.05) with the control. The variation observed in the fibre content of mungbean seeds were probably due to the varying extent of dehulling (Bhatty *et al*., 2000). Dehulling may be responsible for the reduced fibre content compared to the undehulled mungbean flour. According to Maforimbo (2001), the fibre content of dehulled soy bean seed were significantly lower than the whole seed (undehulled seed), suggesting that fibre is more concentrated on the outer seed coat (testa) than in the endosperm. Agugo and Onimawo, (2008), reported that high fibre content makes mungbean a good digestive food.

The total ash content of the raw mungbean seed flour was 3.73% which was significantly different (P<0.05) from other samples except the 8 h soaking which was 3.72%. However, the difference in other samples were slightly significant (3.68%, 3.62%, 3.65%, 3.58% and 3.53%) for 12 h soaking, 5% sodium bicarbonate soaking, 45 min soaking in boiled water, 45 min toasting and 60 min toasting respectively. According to findings, the above results agreed with the results obtained by some researchers such as Agugo and Onimawo, (2008), 3.60%, Sosulki *et al*. (1976), 3.43%, Bhatty *et al*. (2000), 3.31% to 4.05% and Ukwuru (2003), 3.0 to 4.2% for raw soy flour.

The carbohydrate content of the raw mungbean (51.50%) significantly differed (P<0.05) from the other samples. Toasted samples contained the highest carbohydrate of 58.85% and 59.32% for 45 and 60 min toasting respectively. Similar result was obtained by Akaerue and Onwuka (2010), for toasted mungbean flour which showed that toasting significantly increased the total carbohydrate content, from 54.47% to 63.18%. The variations could be attributed to the processing methods (Agugo and Onimawo, 2008).

Functional Properties of the Pre-conditioned Dehulled Mungbean Flours

The effect of some processing treatments on the functional properties of the raw and pre-conditioned dehulled mungbean flour have been shown in table 4. Significant differences (P<0.05) were observed among the control (raw) and the pre-conditioned dehulled samples.

There were significant differences (p< 0.05) between the water and oil absorption capacities of the raw and pre-conditioned dehulled mungbean flour.

Table 4. Mean values for the Functional Properties of the Pre-conditioned Dehulled Mungbean Flour Samples

	WAC (g/g)	OAC (g/ml)	Loose bulk density (g/ml)	Packed bulk density (g/ml)	FC (%)	FS (%)	EC (%)	ES (%)	GT (^{0}C)
Control (raw)	2.88^{a}± 0.04	3.25^{a}±0.01	0.483^{a}± 0.00	0.543^{a}± 0.00	13.75^{b}±0.00	9.38^{a}±0.11	21.62^{a}±0.02	18.44^{a}±0.02	81.31^{b}±0.01
Soaked (8h)	2.65^{b}±0.01	3.20^{b}±0.01	0.440^{ab}±0.00	0.542^{a}±0.00	14.28^{a}±0.03	9.21^{b}±0.04	20.75^{b}±0.00	14.72^{b}±0.00	80.16^{c} ±0.00
Soaked (12h)	2.60^{b}± .03	3.25^{a}±0.01	0.482^{b}±0.00	0.541^{b}± 0.00	13.50^{c}±0.03	9.14^{b}± .00	21.62^{a}±0.02	14.4^{1c}±0.08	81.00c ±0.00
Boiled (45 min)	2.18^{d}±0.00	2.41^{d}±0.01	0.451^{f}± 0.00	0.537^{c}± 0.00	12.83^{c}±0.04	8.91^{c}±0.01	20.15^{c}±0.01	13.41^{f}±0.01	81.60^{d} ±0.14
Toasted (45 min)	2.38^{c}± 0.04	2.34^{c}±0.02	0.458^{c}± 0.00	0.5331^{c}±0.00	11.22^{f}±0.00	7.64^{c}±0.02	16.32^{f}±0.00	13.26^{b}±0.03	79.30^{b}± 0.14
Toasted (60 min)	2.43^{c}± 0.00	2.30^{f}± 0.01	0.464^{d}±0.00	0.533^{d}± 0.00	11.27^{f}±0.04	7.54^{c}±0.00	16.48^{c}±0.00	13.74^{c}±0.02	79.55^{f} ± 0.07

b c d e f g means with different superscripts along a column are significantly different (P <0.05)
Values are mean ± standard deviation of two replications.

Toasted samples (for 45 min and 60 min) had the least oil absorption capacity (OAC) of 2.30g/ml and 2.34g/ml respectively while the boiled sample had the least water absorption capacity of 2.18%. Soaked samples (8h and 12h) gave the highest water (2.88g/g and 2.65g/g respectively) and oil absorption capacity (3.25g/ml and 3.20g/ml respect6ively) which disagreed with the result obtained by Odoemelam (2005), who reported that the oil absorption capacity of some legumes were increased by heat processing. It also disagrees with the result of Lin *et al*., (1974), who reported that heat denaturation improved water imbibing capacity of sunflower proteins.

The loose bulk densities of raw mungbean flour (0.48g/ml) differed significantly (p<0.05) from other samples. In the packed bulk density, there were no significant difference (p> 0.05) between

the control (0.48g/ml) and the sample soaked for 8 h (0.44g/ml).

Toasted flours showed the least packed bulk density of 0.533g/ml but soaked, and boiled flours showed the highest (0.54 and 0.537g/ml respectively).

Consequently, the above results did not conform with the report of Onimawo and Egbekun, (1998) who reported that toasted flour was least important in the formulation of foods while soaked flour were most useful.

The raw mungbean flour had foam capacity of 13.75% which was significantly (p< 0.05) different from the processed flour samples. The soaked samples had greater significant (p< 0.05) in the increasing of the foam capacity than the toasted and boiled flours (Table 4).

Toasted and boiled samples significantly (p<0.05) reduced the foam capacity. Other researchers have reported considerable reduction in foam capacity of heat processed flours: Olapade and Adetuyi, (2007), roasted bambara flour, Odoemelam, (2005) jack fruit flour.

The reduced foam capacity of heat processed flour could be explained on the basis of protein denaturation since proteins are heat liable. Adebowale *et al.* (2005) reported that flexible protein molecules give good foam ability but highly an ordered globular molecule which resists surface denaturation give low foam ability.

There were no significant difference (P > 0.05) between the control and the 12 h soaked samples.

The heat processing affected the foam stability. Toasted samples reduced the foam stability to 7.54% which conforms with the findings of Yasumatsu *et al.* (1972), who reported that heat processing diminished the protein solubility of soy protein by denaturing and reducing the foam stability.

There were significant differences (P<0.05) in the emulsifying capacities and toasted flour, However, the sample soaked for 12 h showed a higher capacity of 21.62% which implies that long socking time increased

Table 5. Mean Sensory Scores of the Pre-conditioned Dehulled Mungbean Cake Samples

Samples	Texture	Colour	Aroma	Taste	General acceptability
601	$4.70^{ab} \pm 2.23$	$4.85^{ab} \pm 2.62$	$5.10^{ab} \pm 2.79$	$4.95^{ab} \pm 2.44$	$5.15^{a} \pm 2.68$
602	$4.50^{ab} \pm 2.44$	$4.95^{ab} \pm 2.70$	$4.30^{ab} \pm 2.36$	$5.55^{a} \pm 2.42$	$4.30^{ab} \pm 2.77$
603	$4.90^{ab} \pm 2.71$	$3.80^{ab} \pm 1.94$	$5.25^{a} \pm 2.65$	$4.20^{ab} \pm 2.76$	$3.95^{ab} \pm 2.48$
604	$3.2^{0b} \pm 2.50$	$3.35^{b} \pm 1.98$	$4.70^{ab} \pm 2.75$	$3.30^{b} \pm 2.64$	$3.25^{b} \pm 2.31$
605	$4.45^{ab} \pm 2.37$	$4.60^{ab} \pm 2.60$	$3.85^{ab} \pm 2.89$	$5.70^{a} \pm 2.66$	$3.85^{ab} \pm 2.41$
606	$5.20^{a} \pm 2.76$	$5.30^{a} \pm 2.62$	$4.40^{ab} \pm 2.70$	$4.60^{ab} \pm 2.64$	$4.65^{ab} \pm 2.89$
701	$4.90^{ab} \pm 2.55$	$4.65^{ab} \pm 2.60$	$4.50^{ab} \pm 3.00$	$4.75^{ab} \pm 2.45$	$4.60^{ab} \pm 2.82$
702	$3.90^{ab} \pm 2.36$	$4.70^{ab} \pm 274$	$4.90^{ab} \pm 2.61$	$4.55^{ab} \pm 2.65$	$5.00^{ab} \pm 2.77$
703	$4.30^{ab} \pm 2.96$	$4.10^{ab} \pm 2.65$	$3.15^{b} \pm 2.28$	$4.15^{ab} \pm 2.43$	$3.60^{ab} \pm 1.93$
704	$5.25^{a} \pm 3.08$	$5.05^{ab} \pm 2.93$	$4.70^{ab} \pm 2.85$	$4.45^{ab} \pm 2.50$	$4.75^{ab} \pm 2.29$
705	$5.45^{a} \pm 2.78$	$5.15^{ab} \pm 2.43$	$4.35^{ab} \pm 2.58$	$4.80^{ab} \pm 2.38$	$4.80^{ab} \pm 2.17$
706	$4.15^{ab} \pm 2.37$	$4.95^{ab} \pm 2.70$	$4.00^{ab} \pm 2.83$	$4.35^{ab} \pm 2.39$	$4.50^{ab} \pm 2.61$

a b c d e f g means with different superscripts along a column are significantly different (P <0.05)
Values are mean ± standard deviation of two replications.9 point hedonic scale.

the emulsifying capacity of mungbean flour.The toasted samples showed the least capacity of 16.32% and 13.26% which conformed with the result of Narayana and Rao, (1982), who reported that heat processing had a reducing effect on the emulsifying capacity of legumes. The toasted flour showed the least temperature of 79.30^{0}C at which gel formation were visually noticed.

The sensory evaluation results of the mungbean – wheat cakes are shown in table 5. Composite flour samples were produced from the dehulled mungbean and wheat flours with mungbean substitution ranging from 10 to 20%.

Taste

The 10% mungbean-substituted cakes had the highest score for taste (5.55), for the sample soaked for 8 h before dehulling, which differed significantly (P<0.05) from the other cakes. The taste observed for the 10% mungbean substituted cake was as a result of the slight beany – flavour imparted on the cake by mung flour. The 20% mungbean-substituted cake had the least score for taste (4.15), for the sample soaked with 5% sodium bicarbonate, may be because of the increase in mungbean flour.

Colour

The 10% mungbean-substituted cake for samples soaked in boiled water, had the poorest colour which differed significantly (P <0.05) from other samples. Samples toasted for 60 min and the ones soaked for 8 h gave the highest score (4.95 and 4.95) respectively. This may be because of the high temperature and increased time of toasting and soaking.

Texture

The cake from the 20% toasted mungbean-substituted flour had the best texture (5.45). This may be adduced to the increased drying time. Boiling also affected the texture, the 10% mungbean substituted cake had the lowest score (3.20) which was significantly different (P<0.05) from the others.

Aroma

The 10% mungbean- substituted cake gave the best aroma with the samples soaked with 5% sodium bicarbonate and it was significantly different (P<0.05) from others (5.25).

When the mungbean flours were increased to 20%, the cake produced from 5% sodium bicarbonate soaked mungbean samples, had the lowest score (3.15) which were significantly different (p<0.05) from the others, these imply that increased percentage of mungbean flour decreased the aroma.

General Acceptability

With respect to the general acceptability, the cake produced with 10% of the 12 h soaked mungbean flour was mostly preferred. This was because wheat flour has been of excellent quality for cake production due to its peculiar characteristics, especially the gluten content. It could obviously be seen from this study that 10% mungbean- substituted flours had a good potential in cake making compared to 20% mungbean- substituted flours. The high carbohydrate content of mungbean flour especially the quality of starch it contains had made it possible for it to form good cake on heating (Kim *et al*., 2007).

CONCLUSION

This study has shown that the wet treated samples (soaking and boiling) gave the highest dehulling efficiency when compared with toasting method. Among the wet treated samples, the ones soaked in boiled water for 45 min gave the highest dehulling efficiency followed by the ones soaked for 12 h and 8 h respectively.

Apparently, the pre-conditioning treatments had significant ($P< 0.05$) effect on proximate composition of the mungbean flours. Soaking and boiling increased the moisture content while toasting increased the carbohydrate content but reduced the moisture, protein, fibre and fat content.

The functional properties of the dehulled mungbean flour were slightly better than its undehulled counterparts reported in previous studies and compared favourably with other legumes, hence it can find useful application in the food industry especially in infant food formulation and baked products.

The results have shown that mungbean can be dehulled better when soaked or boiled and also be better utilized when dehulled. Furthermore, that mungbean flour can be used as composite flour for cake production, especially at 10% substitution to wheat flour.

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Appendix

601	- Samples soaked for 12 h	Mungbean: Wheat 10: 90
602	- Samples soaked for 8 h	
603	- Samples soaked with sodium bicarbonate for 30 min	
604	- Samples soaked in boiled water for 45 min	
605	- Samples toasted for 45 min (120^{o}C)	
606	- Samples toasted for 60 min (100^{o}C)	
701	- Samples soaked for 12 h	Mungbean: wheat 20: 80
702	- Samples soaked for 8 h	
703	- Samples soaked with sodium bicarbonate for 30 min	
704	- Samples soaked in boiled water for 45 min	
705	- Samples toasted for 45 min (120^{o}C)	
706	- Samples toasted for 60 min (100^{o}C).	