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RESEARCH ARTICLE

Physicochemical and Cooking Properties of a Novel Food: Alhydwan (*Boerhavia elegana Choisy*) Seed Flour

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Abstract

This study is an important approach for providing against the food-supply crisis especially in developing countries. Therefore, alhydwan (*Boerhavia elegans Choisy*) seed flour was evaluated for physicochemical and cooking properties. The findings of physicochemical showed that alhydwan number of seeds per gram was 345, so the weight of 100 seeds was approx. 0.35 g. The length, diameter and thickness of seeds were 4.25, 2.20 and 1.35 mm, respectively. The alhydwan flour had a bulk density of 0.53 g/mL, results on hunter color values (L*, a*, b*) indicated a sample total color difference (ΔE) of 31.42. This work is valuable in the aspect of the development of novel food material; our findings revealed that the alhydwan could be exploited as a basic raw material to develop new low cost nutritious functional foods.

Keywords: Food-supply crisis**,** alhydwan, *Boerhavia elegans Choisy*, physicochemical, cooking properties.

Introduction

Legumes have been well known as food resources that posses great properties in additional to offering various health benefits (Morrow, 1991; Tharanathan and Mahadevamma, 2003). Additionally legumes are considered as the second largest sources of human food after cereal, particularly in developing countries, especially for those with low income. They supply a cheap source of protein and are used for enriching variety of foods (Kaur *et al.,* 2009). Thus, from between the wide array of plant produce, legumes and seeds constitute a major portion and are capable of contributing substantially as a source of nutrition (Bhat, 2011). In an attempt to find inexpensive plant-based materials for developing new food products, as well as protein supplements, wide research has embarked on the potential of underutilized dicotyledonous seeds (with substantial traditional knowledge) for humans as well as in livestock consumption (Bhat and Sridhar, 2008; Bhat, 2011). Malnutrition in lactating women and children is evident in developing countries, because of inadequate supply of protein diets, can be indemnified by wild legumes (Vadivel and Janardhanan, 2001). Seeds alhydwan are common in the of south of Yemen, commonly known as alhydwan in yemen, is an edible herbaceous member of the Nynctaginaceae family (Boulous, 1988). *Boerhavia* is a genus of 10 to 40 species, almost all of which are widely distributed in tropical and subtropical regions worldwide (Fosberg, 1999; Spellenberg, 2003).

Some of the species are extraordinarily plastic or polymorphic and are treated as complex groups (Chen and Wu, 2007). A number of species of the same genus are used widely in the traditional system of medicine in many countries (Olaleye *et al.,* 2010). Being one of the compositions of the traditional cuisine of Yemen with long history of uses, alhydwan is now gaining popularity throughout the country as one of the staple ingredients in the manufacture of porridge, desserts and savory products. It is also eaten as a supplement mixed in bread and cakes, characterized by texture and good flavor (AL-Farga *et al.,* 2014). Several studies have reported about legumes and cereals. However, up to date, as far as our knowledge is concerned, literature that reports of *Boerhavia elegana Choisy* seed based study conducted anywhere in the world can hardly be found. This study therefore, was intended to provide statistical information on the same, in an attempt to fill this knowledge gap and determine potential applicability of alhydwan seed flour in other novel food systems.

Materials and methods

Collection of seeds: Dried alhydwan seeds were brought from a local farm in Wad Hadramout City, Yemen in June 2015 after harvesting and transported to the Functional Ingredients and Healthy Foods Laboratory of Jiangnan University, Wuxi city, China. The seeds were sorted and milled into flour using a laboratory scale hammer mill (Tianjin Taisite Instrument Co., Ltd., Tianjin, China).

Flour was then screened through an 80 mesh sieve, put in polyethylene bags and stored in a refrigerator at 5°C until use.

Total energy (caloric value): Energy was calculated according to the method of Osborne and Voogt (1978) and Sukker (1985) using the Atwater factor. According to the method, 1 g of fat provides 9 K calories, 1 g of protein provides 4 K calories and 1 g of carbohydrates provides 4 K calories.

Physical characterization of alhydwan seeds: Weight of 100 seeds, number of seeds per gram, length, width and thickness were estimated.

Bulk density: The Bulk density of the alhydwan flour was estimated according to the method of Du *et al.* (2014). Briefly, a triplicate desired amount of flour sample was gently transferred into a 10 mL pre-weighed graduated cylinder up to the full mark. The bottom of the cylinder was gently tapped onto a laboratory repeatedly until no more reduction in the sample level was observed. The bulk density was calculated as a factor of the weight per unit volume of the sample (g/mL).

Color parameters: The color parameters of the alhydwan flour were determined using a Hunter Lab digital colorimeter (TC-PIIG system; Beijing Optical Instrument Co., Ltd., Beijing, China). A cylindrical plastic dish (58 mm in dia and 15 mm in depth) containing sample (100 mg) was placed at the light port (50 mm in dia). The instrument was initially calibrated with a pure white standard plate (L*=99.58, a*=0.12, b*=0.07). The L*, a*, and b* values of the sample were read directly by the TC-PIIG automatic color difference meter. The color difference indicator values of ΔL (lightness-darkness), Δa* (redness-greenness), Δb* (yellowness-blueness), and ΔE* (total color difference) were calculated, as follows:

$$\Delta E = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})} \quad (1)$$

Where:

$\Delta L^* = \Delta L^*_{sample} - \Delta L^*_{standard}$,
$\Delta a^* = a^*_{sample} - a^*_{standard}$ and
$\Delta b^* = b^*_{sample} - b^*_{standard}$

Water absorption index and water solubility index: The water absorption index (WAI) and water solubility index (WSI) of the alhydwan seed flour were estimated according to the method of Kaur and Singh (2005) with minor modifications. Alhydwan flour sample (2.5 g) was dissolved in 30 mL distilled water and cooked in water bath at 70ºC for 30 min thereafter; cooked paste was cooled at room temperature. Transferred to preweighed centrifuge tubes and centrifuged at 3000 g for 20 min. The supernatant was poured into a pre-weighed evaporating dish to define its solid content and the sediment was weighed.

The weight of dry solids was recovered by evaporating the supernatant overnight at 105°C. The water absorption index (WAI) and water solubility index (WSI), were calculated using the following equations:

$$\text{WAI (g/g)} = \frac{\text{Weight of sediments}}{\text{Weight of flour sample}} \quad (2)$$

$$\text{WSI (g/100 g)} = \frac{\text{Weight of dissolved solids in supernatant} \times 100}{\text{Weight of flour sample}} \quad (3)$$

Cooking properties: Minimum cooking time, water uptake ratio, elongation ratio, gruel solid loss and length–breadth ratio were determined based on the available standard methods (Singh *et al.,* 2004; Yadahally *et al.,* 2009).

Minimum cooking time: Minimum cooking time was determined according to the method outlined by Yadahally *et al.* (2009). In brief, about 200 mL of deionized water in 250 mL beaker was boiled in a standard laboratory hot-plate (Wiggen Hauser, HPS 630). Approximately 50 g of alhydwan seeds (cotyledons) were boiled with the water being added at regular intervals to maintain the water level constant. The cotyledons were removed from the beaker at 1 min interval by using a sterile spatula and tested for softness by pressing between finger and thumb. The minimum cooking time was determined based on the time taken for the raw cotyledon to cook up to the required softness.

Water uptake ratio: Approximately fifty grams of seed cotyledons were cooked for minimum cooking time in 250 mL distilled water in a boiling water bath, drained and blotted to remove superficial water wiped using filter papers. The samples were weighed and the water uptake ratio was calculated as the ratio of weight gained after cooking to weight before cooking.

Elongation ratio: The cumulative lengths of all the 10 seeds cotyledons were determined before and after cooking for minimum cooking time. The elongation ratio was determined as the length of cooked seeds divided by the length of raw seeds.

Gruel solid loss: Approximately 50 g of seed cotyledons were cooked in distilled water for a minimum cooking time in 250 mL of distilled water in a boiling water bath, the gruel was transferred to 400 mL beakers after several washing and the volume made up with distilled water. The solids were subsequently weighed and gruel solid loss was calculated as percentage. Aliquots gruel was evaporated to dryness at 110°C.

Length-breadth ratio: The cumulative length and breadth of all 10 cotyledons was determined after cooking for minimum cooking time. The length-breadth ratios of the 10 cooked seeds were measured by dividing the cumulative length to the cumulative breadth of cooked cotyledons.

Table 1. Color parameters of alhydwan (*Boerhavia elegana choisy*) seeds flour.

Hunter color parameters	Color mean values
L*	73.88±0.089
a*	3.42±0.078
b*	14.43±0.090
ΔE*	31.42±0.806

Results represent the mean±SD of the analysis performed in triplicate.

Table 2. Physicochemical properties of alhydwan seed flour compared with legume flour.

Parameters	Bulk density (g/mL)	WAI (g/g)b	WSI (g/100 g)c
Alhydwan seeds	**0. 53 ±0.006**	**7.13±0.31**	**31.13±0.22**
Pinto bean[d]	0.680 ± 0.00	4.27 ± 0.08	19.44 ± 0.79
Lima bean[d]	0.782 ±0.00	4.82 ±0.13	29.14 ± 0.67
Small red bean[d]	0.683 ±0.00	4.79 ± 0.13	22.15 ±1.85
Red kidney bean[d]	0.679 ± 0.00	4.57 ± 0.15	21.69 ± 0.12
Black bean[d]	0.543 ± 0.01	4.40 ± 0.06	20.97 ± 0.00
Navy bean[d]	0.690 ± 0.01	4.31 ± 0.13	25.92 ± 1.26
Black eye bean[d]	0.764 ± 0.01	4.09 ± 0.00	25.04 ± 0.63
Mung bean[d]	0.798 ± 0.01	5.64 ± 0.12	20.76 ± 0.64
Lentil[d]	0.816 ± 0.01	4.76 ± 0.03	26.15 ± 0.59
Chickpea[d]	0.573 ± 0.00	6.13 ± 0.02	24.08 ± 0.92

[a]All data represent the mean of triplicates. [b]Water absorption index, [c]Water solubility index, [d]Du *et al.* (2014).

Scanning electron microscopy: Scanning electron microscopic studies were carried out using a scanning electron microscope (Quanta-200 FEI, Netherland). The samples were coated before loading to SEM. The coated samples were loaded into the system and the image was viewed under 1.0 KV potential using secondary electron image. The image was captured using 11.20 mm Ricoh Camera of 600x Mag (Wang *et al.,* 2008).

Results and discussion

Total energy (Caloric value): The calorific value for the fat, carbohydrates and protein was found to be 0.49, 0.99 and 0.58 kcal/g, respectively, with carbohydrates giving higher energy. From this data, alhydwan seeds can be considered as a good source of calories. It is well known that a calorie is a measure of energy, the energy can be used immediately or stored for later use, and foods have calories. That is, foods supply the body with energy, which is released when foods are broken down during digestion. Thus, energy enables cells to do all of their functions, including building proteins and others substances needed by the body (Duyff and Ada, 2011).

Physical characterization: The number of seeds per g was 345, so the weight of 100 seeds was approx. 0.35 g. The length, diameter and thickness of seeds were 4.25, 2.20 and 1.35 mm, respectively.

Color parameters: The color parameters of alhydwan seed is given in Table 1. The results of the color measurements of the flour sample by Hunter color values (L*, a*, b*) demonstrated a total color difference (ΔE) of 31.42. It has been reported that the differences in color can be attributed to differences in pigments contained in the sample, which might usually depend on the botanical origin of the plant, in addition, to the composition of the flour (Njintang *et al.,* 2008).

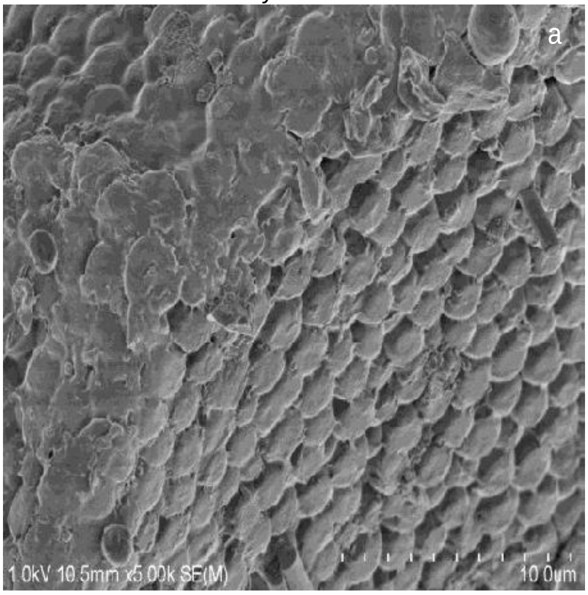
In this study, the alhydwan seeds sample retained their original colors after sun drying and milling.

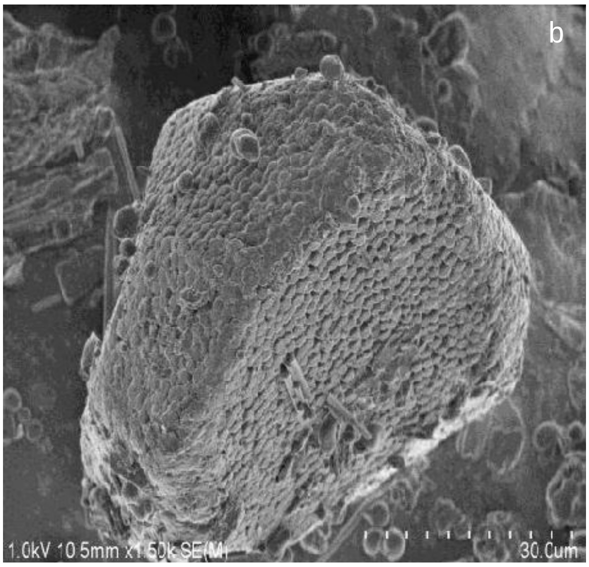
Bulk density: The bulk density for alhydwan flour was 0.53 g/mL as shown in Table 2. This result was agreed with the value reported by Kaur and Singh (2005), who found the bulk densities of different chickpea varieties ranged from 0.54 g/mL to 0.57 g/mL. Based on this, it was suggested that the alhydwan seed flour could be similar in bulk density of legume flour which may play an important role in formulation of foods that require low bulk density such as weaning foods (Milán-Carrillo *et al.*, 2000).

Water absorption index and water solubility index: Water absorption index measure the volume occupied by starch after it swells in surplus water and refers to integrity of starch in aqueous dispersions. The WAI of alhydwan seeds was 7.13 g/g, this value, is higher than those found by Du *et al.* (2014) in whole legume flour, which ranged between 4.09 and 6.13 g/g. WAI is related to gelation capacity of biomacromolecules and hydrophilicity of major components, such as protein and starch in the flour (Kaur and Singh, 2005). The results demonstrate that amorphous region of alhydwan starch can greatly swell by absorbing water, causing the starch to have a high WAI. The WSI refers to extent of solubility of molecules of the flour components in water. The WSI was 31.13 g/100 g. Similar to WAI, the WSI value was also higher compared to those reported by Du *et al.* (2014) on whole legume flour. Amount of protein-starch and amylase-lipid complexes formed in the process of heating could affect the WSI (Sathe *et al.,* 1982).

Cooking properties: The water uptake ratio of alhydwan was 1.02±0.04; minimum cooking time (min) required was 21.01±1.01, elongation ratio was 1.12±0.02; Gruel solid loss was 3.59±0.11% and L/B ratio was 1.23±0.33.

Fig. 1a and b. Scanning electron microscopic pictures of whole alhydwan seed flour.





High bulk density of the seeds might have resulted in low water uptake ratio. Moreover, the ratio L/B affects the loss of solid gruel, wherein, low L/B ratios index a smaller surface area for minimal contact with water. Therefore, the gruel solid losses of alhydwan seeds index a lower loss of seed solids during cooking, which is an index of reduced wastage, desirable attribute during alhydwan processing. On the other hand, reduced cooking time might be advantageous considering the fuel consumption, especially in the developing and under developed countries.

Scanning electron microscopy (SEM): In order to understand the morphology of *B. elegana Choisy*, SEM analysis was performed and the results are presented in Fig. 1a and b.

Scan Electron Microscopy has proven to be a useful tool for studying the morphological changes that take place in the starch granules. SEM was used to follow the morphological changes in starch granules alhydwan seed flour and the results are presented in Fig. 1a and b. It can be observed from the figure that *B. elegana Choisy* consisted starch granule within intercellular space covered with cell wall (fiber). This suggested the presence of polysaccharides (gum). Unfortunately, up to date there is no information available in the literature regarding seed to corroborate these facts.

Conclusion

This study evaluates the physicochemical and cooking properties of the underutilized alhydwan seed flour. Alhydwan flour showed highest WSI (water solubility index), as compared to some legumes flour. The highest WSI of alhydwan flour make it potentially useful in flavor retention, improvement of palatability and extension of shelf-life in bakery products. High WSI of alhydwan flour make it a good body providing agent and thus can be used as a thickener or gelling agent in various food products. Overall, findings of the present study revealed alhydwan seed flour has a great potential and can be used in food industry especially for bakery products and products that require the absorption of large amounts of water, it can be efficiently used for a promising way of diversifying its uses in extract gum due to high gum content.

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