PHYSICO-CHEMICAL PROPERTIES AND PRODUCT CHARACTERISTICS OF LOCALLY GROWN SOYBEAN VARIETIES OF ETHIOPIA

Fozia **Muhsin**[1] and Adamu **Zegeye**[2*]
[1]Consultant, Addis Ababa, Ethiopia
[*2]School of Chemical and Bioengineering, Food Engineering Chair, AAiT, Addis Ababa University, Ethiopia,
*Email: *adamuzegeye@yahoo.com*

Abstract
The study aimed at determining the physicochemical properties and flour characteristics of Clark 63K and SCS1 soybean varieties obtained from Jimma Agricultural Research Center, Ethiopia. The former is a released variety and the later is in pipeline. Their seed color, shape, size, seed density; hundred seed mass, hydration and swelling capacities, hydration and swelling indices, hydration and swelling coefficients were analysed according to the standard procedures. The proximate composition of the whole bean flour; bulk density , water absorption index (WAI), water solubility index (WSI), oil absorption capacity (OAC), emulsion activity(EA), emulsion stability (ES), foaming capacity (FC) and foaming stability (FS) of the full fat soy flour were also determined as per the recommended methods. All samples were taken in triplicate and the data were subjected to analysis of variance using SPSS statistical software. The results showed no significant difference between the two in hundred seed mass, seed density, hydration capacity and index, swelling capacity and index, and hydration coefficient (p<0.05). However, the Hilum color of Clark 63K is black and that of SCS1 is yellow which places SCS1 in a better position in terms of preference. Clark 63K was found to contain 39.7 % protein and 20.9 % fat whereas SCS1 has 37.5% protein and 20.8 % fat. Except in OAC, there was no statistically significant difference between the two varieties in the other functional properties. In conclusion, both varieties have shown good performance in becoming a potential source of nutrients, and suitable raw materials for product development.

Keywords: Ethiopia, product characteristics, physico-chemical properties, soybean varieties

Received: 09.07.2018 Reviewed: 5.10.2018 Accepted: 24.10.2018

1. INTRODUCTION

Soybean [*Glycine max (L.)* Merrill] originated in Eastern Asia, probably in north and central China, and constitutes an important component of the traditional popular diet in these regions (Berk, 1992). Soya bean is a potential source of protein and fat. Soy flour, concentrate and isolate are the most popular products used to enrich different food items deficient in protein. High-quality soybeans have desirable levels of certain characteristics which include physical properties, chemical compositions and functional properties (Brumm, 2006). If genotypic correlations between seed density and yield are low, selection for increased density could provide an efficient way to improve protein concentration without affecting seed yield (Li and Burton, 2002). Larger seeds have fewer hulls and therefore less fiber can be obtained. Seed count is a varietal characteristic that is influenced by growing conditions, and is determined by counting and then weighing (Brumm, 2006). Many processors want yellow-hilum soybean (also known as clear or white-hilum), as the darker hila may affect the color or clarity of the final processed product. The hilum color is a genetic characteristic of a soybean variety. Hilum color is identified by visual inspection (Brumm, 2006). Commercial soybean constitutes approximately 8% hull, 90% cotyledon, and 2% hypocotyls and plumule. Functional characterization of proteinous products like that of soy products can be generalized as hydration, emulsification, textural, and rheological (Fenemma, 1985).

In Ethiopia, soybean is being used at industrial level by a very few companies. Defatted soy flour, soybean oil, soymilk, soymilk curd are being produced in Ethiopia. Researchers in the field of agriculture have been trying to produce high yielding, disease tolerant and draught resistant varieties. Soybean varieties such as Clark 63K and SCS1 are among the varieties developed by *Jimma* Agricultural Research Center, Ethiopia. However, a variety like SCS1 is in pipeline requiring additional investigation. In fact, the variety Clark 63K can also be revisited to evaluate its performance in terms of nutritional value and suitability for processing at a factory level. Therefore the present study was carried out with the objective of determining the physicochemical properties and product characteristics of the two soybean varieties.

2. MATERIALS AND METHODS

Materials and sample preparation

The selected soybean varieties, namely Clark 63K (Fig 1) and SCS1 (Fig 2) were collected from *Jimma* Agricultural Research Center in Ethiopia upon the recommendation of the Center. Clark 63K is a released variety, and is being widely cultivated and distributed in *Jimma* area and more recently in southern regions of the *Gurage* Zone, whereas SCS1 is a new variety in the pipeline to be released.

Fig 1. Clark 63K soybean variety

Cracking and dehulling soybean varieties

Cracking and dehulling of both varieties were done without any kind of preconditioning. After the necessary cleaning process, the raw seeds were fed into a decorticator type AB-ALVAN BLANCH No 27/02545 and the beans were cracked. Then the cotyledons and the hull were separated. Finally the hull was weighed and its percentage, as compared to the initial seed weight, was calculated. Dehulling was done using a huller ALVAN BLANCH model No 3 Sw/2m to reduce the fiber content after cracking and to improve the efficiency of extraction.

Fig 2. SCS1soybean variety

Development of full fat soy flour (FFSF)

The cracked and dehulled two soybean varieties were separately milled with a disc mill FRITSCH D555743-*Idar-Oberstein* Germany, and sieved using 710 µ sieve to get a uniform particle size. Finally, the full fat soy flour which is the final product was packed in air tight plastic bags.

Determination of physical properties

Hundred seed mass and seed density

One hundred seed mass was determined by counting hundred seeds and weighing, and the results were expressed as the mean of triplicates. Seed density was determined according to the method of Alfonso *et al.*(2007). One hundred seeds were weighed and transferred into 100 ml measuring cylinder containing 50 ml of tap water. The seeds were allowed to soak for 10 min for equilibration, and the volume of water displaced was recorded at room temperature. The mass and volume were used to calculate the seed density as g/ml.

Bulk density

Bulk density (g/cm3) was determined by filling a container of known volume with full fat soy flour sample followed by weighing.

Determination of physicochemical properties

Chemical composition

The proximate analysis of raw materials and products was conducted using official methods as described in AOAC (2000).

Hydration and swelling coefficient

The raw bean seeds were soaked in distilled water for 24 h. The volumes of the beans before and after soaking were estimated by water displacement. The hydration coefficient was calculated as the percentage of increase in mass of beans. The swelling coefficient was calculated as percentage of volume of beans after soaking to the volume before soaking according to the method reported by Yusuf (1978).

Hydration, swelling capacities and indices

Hydration, swelling capacities and indices were determined by Bishnosi and Khetarpaul (1993). About 100 g of beans was put in a measuring cylinder containing 100 ml water, and left overnight at room temperature. The next day, swollen seeds were reweighed after draining the water through filter paper. Hydration capacity per seed was determined by dividing the mass gained by the seed to the number of seeds present in sample. Swelling capacity per seed was calculated as the volume gained by the seeds divided by the number of the seeds. Hydration index was calculated as the ratio of the average hydration capacity per seed to the mass of one seed. The swelling index was calculated as the ratio of swelling capacity per seed to volume of one seed (ml).

Determination of functional properties of FFSF

Water absorption index (WAI) and Water solubility index (WSI)

Water absorption index (WAI) and water solubility index (WSI) of the flours were determined as per the standard procedure. For the determination of WAI, 1.25 g of extruded and ground sample (100 mesh) was suspended in 15 ml of distilled water. The sample was incubated at 25°C with constant stirring for 30 min and then centrifuged at 3000 rpm for 5 min using a centrifuge type UJ III Germany 1972. Supernatant liquid was poured into a tarred evaporating dish and dried at 100 ± 5°C for 4 h. Weight of the remaining gel was taken as WAI and expressed as g/g of dry sample. The supernatant taken from determination of WAI was dried by evaporation at 105°C for overnight. Then WSI was calculated as a ratio of dry residue to the original mass (1.25g) and expressed as mean percentage of dry solid.

Emulsion activity (EA) and emulsion stability (ES)

Determination of emulsion activity (EA) and stability (ES) was performed according to the Yasumatsu *et al*. (1972). The emulsion (about 2g sample, 20 ml distilled water and 20 ml soybean oil) was prepared in a calibrated centrifuge tube. The emulsion was centrifuged at 2000 rpm using a centrifuge (Universal Jambo III (UJ3) Germany, 1972) for 10 min. The ratio of the height of the emulsion layer to the total height of the mixture was calculated as emulsion activity expressed in percentage. The emulsion stability was estimated after heating the emulsion contained in a calibrated centrifuge at 800°C for 30 min in a water bath; cooling for 15 min under running tap water and centrifuging at 200 g for 15 min. The emulsion stability, expressed in percentage, was calculated as the ratio of the height of emulsified layer to the total height of the mixture.

Oil absorption capacity (OAC)

Oil absorption capacity was determined according to Beuchat (1977). About one gram of the sample was mixed with 10 ml oil (pure soybean oil) for 30 s in a mixer. The samples were allowed to stand at room temperature for 30 min, centrifuged at 5000 rpm using a centrifuge (UJ III Germany, 1972) for 30 min, and the volume of the supernatant was noted in a 10 ml graduated cylinder. Density of oil was taken as 0.895g/ml.

Foaming capacity (FC) and foaming stability (FS)

The method described in Coffman and Gracia (1977) was used, accordingly, 2 g sample was whipped with 100 ml distilled water for 5min in Panasonic home blender (type Panasonic MX-J120P), and poured in to a 250ml graduated cylinder. The total volume at time intervals of 1min, 30 min, 1 h, 2 ½ h, and 3 h was noted.

Experimental design and data analysis

The experiment was conducted in a completely randomized design, and the data were subjected to analysis of variance using SPSS version 13.0 statistical software. The means were then compared and the statistical significance between them was set at 5% level.

3. RESULTS AND DISCUSSION

The amount of hull, cotyledon and hypocotyls obtained by cracking and dehulling Clark 63K and SCS1 soybean varieties is shown in Table 1.

Table 1. Percentage of parts of Clark 63k and SCS1 soybean varieties

No	Proportion of parts of the Soy bean	Clark 63k (%)	SCS 1 (%)
1	Cotyledon and hypocotyls	87.54	91.48
2	Hull	12.46	8.52
3	Whole bean	100	100

Physical properties

Color and shape

Both varieties have industrial quality characteristics. Basically, industrial quality characteristics of soybeans are yellow in color and spherical in shape (Berk, 1992). SCS1 has yellow hilum color whereas Clark 63K possesses black hilum color. Traditionally, processors prefer yellow hilum color soybeans to avoid any color effect on the final product due to a darker hila (Tofu, Soymilk, Natto,etc.) (Brumm, 2006)

Hundred seed mass and seed density

Clark 63k and SCS 1 were found to have hundred seed mass of approximately 15.198 gm/100 seeds and 15.531 g/100 seeds, respectively. These values are not significantly different ($p<0.05$) with each other. Yimer (2007) reported that the hundred seed mass of locally grown soybean varieties of *Awassa* and *Belessa* was 14.05 g/100 seeds and 14.18 g/100 seeds, respectively. This result proves that Clark 63k and SCS 1 have relatively higher 100 seed mass value than *Awassa* and *Bellessa*. When compared with oil seed quality standard (18-19 g/100seeds) reported by Berk (1992), the 100 seed mass of Clark 63K and SCS1 have smaller values. On the other hand, they registered better values when compared to *Natto* Manufacturing soybean quality standard (9-10 g/100 seeds). Clark 63K and SCS 1 have a seed mass within the range of those of commodity types (13.7-16.67 g/ 100seeds) (Brumm, 2006).

The seed densities of Clark63K (1.68g/ml) and SCS1 (1.67 g/ml) are not significantly different ($p<0.05$) from each other. Clark 63K and SCS 1 have higher seed densities than locally grown soybean varieties known as *Awassa and Bellesa* (Yimer, 2008). Their densities are close to the values reported by Li and Burton (2000). Genotypic correlation between seed density and protein is positive, whereas correlation between oil and density is negative (Li and Burton, 2002). Therefore, seed density can be taken as one means of seed variety selection in order to identify a variety with high protein concentration.

The full fat soy flour of Clark 63K has a bulk density (BD) of 0.600 g/ml and that of SCS1 is 0.625 g/ml. Yimer (2008) reported that the BD values of soybean varieties of *Awassa and Belessa* FFSF are 0.64g/ml and 0.6 g/ml, respectively. The result indicates that the BD values of Clark 63K and SCS1 are almost similar to that of *Awassa and Belessa*. Okaka and Potter (1979) also reported cowpea's bulk density (0.6 g/ml) is similar to that of SCS1. In the current study Clark 63K and SCS1 were found to contain higher BD than what was reported about commercial soy flour (0.38 g/ml) by Edema *et al*., (2005). According to Onimawo *et al.* (1998), the bulk density of ground nut is between 0.6 and 0.75 g/ml, thus justifying BD values of Clark 63 K and SCS1 to be within the range. Details of the results are given in Table 2.

Table 2. Description of the physical properties

Cultivars	Hundred seed mass [g]	Seed density [g/ml]	Bulk* Density [g/ml]	Bean color	Hilum color	Shape	Size
Clark 63K	15.20 ± 0.54[a]	1.17 ± 0.0420[b]	0.600±0.08[c]	Yellow	Black	Semi Spherical	medium
SCS 1	15.53 ± 0.195[a]	1.17 ± 0.0416[b]	0.625±0.01[c]	Light Yellow	Yellow	Spherical	medium

Means bearing the same letters in the same column are not significantly different from each other at (p<0.05)
All values are means of triplicates ± SD
*the bulk density of the full fat soy flour

Physicochemical properties

Hydration and swelling capacities and indices, & hydration and swelling coefficients

The physico-chemical properties of clark63k and SCS1 varieties are presented in Table 3. Clark 63K has been found to have a hydration capacity of 0.124g/seed, hydration index (0.838), hydration coefficient (140.0%), swelling capacity (0.118g/seed), swelling index (0.936), swelling coefficient of 142.2%. Whereas SCS1 registered a hydration capacity of 0.133g/seed, hydration index (0.869), hydration coefficient (140.1%), swelling capacity (0.127g/seed), swelling index (0.977), and swelling coefficient of 150.0 %.The hydration capacity, swelling capacity, hydration index, swelling index, hydration coefficient of both varieties are not significantly different (p<0.05) from each other. Indeed, SCS 1 showed greater values in the parameters than Clark 63K. Notably, there is a significant difference in swelling coefficient between the two varieties (p<0.05). The hydration and swelling coefficient Clark 63K and SCS1 are significantly lower than Faba Bean seeds reported by El-Refai *et al*., (1988), and the hydration capacity, swelling capacity, hydration index and swelling index values are lower than that of chickpeas reported by Williams *et al*.(1983). Two soybean varieties, *Awassa and Belessa*, showed higher values of hydration and swelling capacity, hydration and swelling index and lower value of hydration coefficient than that of Clark 63K and SCS 1 whereas their swelling coefficients are closer (Yimer, 2008).

The protein contents of Clark 63K and SCS1 are found to be nearly 39.7 % and 37.5 %, respectively. Similarly Clark 63K registered nearly 20.9 % fat and SCS1 20.8 % fat. The details of the proximate composition of the two soybean varieties are listed in Table 3.

Table 3. Physico-chemical properties and composition of soybean varieties

Cultivars	Hydration capacity (g/seed)	Swelling capacity (ml/seed)	H Hydration index	Swelling index	Hydratio coefficien.	Swelling Coefficient
Clark 63K	0.124±0.00[a]	0.118±0.00[b]	0.838±0.00[C]	0.936±0.000[d]	1.400±0.000[e]	1.422±0.056[f]
SCS 1	0.133±0.00[a]	0.127±0.00[b]	0.869±0.002[C]	0.977±0.001[d]	1.401±0.011[e]	1.500±0.010[g]
	Moisture(%)	**Fat(%)**	**Protein(%)**	**Carbohy.(%)**	**Ash (%)**	**Crude fibre(%)**
Clark 63K	6.312±0.028	20.855±0.011	39.659±0.143	27.972±0.092	4.786±0.267	6.732±0.013
SCS 1	6.871±0.007	20.760±0.091	37.495±0.146	30.525±0.170	4.220±0.038	7.001±0.668

*Means bearing the same letters in the same column are not significantly different from each other at (p<0.05)
*All values are means of triplicates ± SD

Functional properties of full fat soy flour (FFSF)

Clark63K showed WAI values of 2.917 and SCS1 2.904, respectively. The WSI values of Clark 63K and SCS1 are 35.594%, 33.379%, respectively. In general, WAI and WSI values of Clark 63K and SCS1 showed that SCS1 has better product characteristics than Clark 63K.

The oil absorption capacity (OAC) of Clark 63K is 1.730 g/g and SCS1 is 1.849 g/g. This result indicated higher values than reported (0.844 g/g) by other researchers (Yusuf *et al*., 2007). Yimer (2008) reported that soybean varieties of *Awassa* and *Belessa* flours have oil absorption capacity of 1.82 g/g and 1.44 g/g, respectively. This shows that *Awassa* has lower OACthan that of SCS1 and higher than that of Clark 63K. Whereas, *Belessa* possesses lower OAC than Clark 63K and SCS1. When the OAC values of Clark 63K and SCS1 are compared, SCS1 has significantly higher ($p<0.05$) oil absorption capacity than Clark 63K.

The emulsion activity (EA) of Clark 63K is 45.24% & of SCS1 is 43.74%. Yimer (2008) reported that *Awassa* and *Belessa* soybean flours have emulsion activity of 49.06% and 46.75%, respectively, which is slightly higher. The emulsion stability (ES) of FFSF from Clark 63K was found to be 44.07% and that of SCS1 was 44.68 %. The details of the results are presented in Table 4.

Foaming capacities of Clark 63K and SCS1 are 36 ml and 32 ml, respectively. These soy flour products have higher foaming capacity than that of *Awassa* (70%) and *Bellesa* (66%) soybean varieties (Yimer, 2008). The foaming stability of Clark 63K is 95% and that of SCS1 is 81.25%. The foaming capacity and stability of Clark 63K are higher than that of SCS1 (Table 5).

According to Darewicz *et al.* (2000), foaming capacity of soy proteins increased during progressive enzymatic hydrolysis due to the increase in solubility and the formation of peptides of reduced molecular weight. These peptides could be transformed and absorbed in the oil-water interface more easily. However, hydrolysis led to decreased foaming stability possibly caused by peptides of decreased size and increased flexibility (Chatziontonion *et al*., 2007; Darewicz *et al.*, 2000). Grahams and Philips (1996) linked good foaming ability to flexible protein molecules that can reduce surface tension while highly ordered globular protein, gives low foaming ability. One may therefore suggest that Snake gourd protein may contain high concentration of flexible protein (Yusuf *et al.*, 2007; Grahams and Philips, 1996).

Table 4. Values of functional properties of the full fat soya flours of the two varieties

Cultivar	WAI	WSI (%)	OAC (g/g)	EA (%)	ES (%)
Clark 63k	2.918 ± 0.18[a]	35.594±0.10[a]	1.730 ± 0.24[a]	45.24 ± 0.00[a]	44.07 ± 2.11[a]
SCS1	2.904 ± 0.14[a]	33.379±0.20[b]	1.849 ± 0.24[b]	43.74±0.77[a]	44.68 ±2.57[a]

Means bearing the same letters in the same column are not significantly different from each other at p<0.05
All values are means of triplicates ± SD

Table 5. Foaming capacity and stability of FFSF

Cultivar	Sample type	Liquid Vol. before foaming (ml)	Liquid Vol. after foaming (ml)	Foaming capacity (%)	Foam stability (%)	Foam height [ml]				
						1 min	½ h	1 h	2 h	3 h
Clark 63K	FFSF Flour	100	98	36	95	36	30	22	12	8
SCS1	FFSF Flour	100	98	32	81.25	32	26	22	18	12

4. CONCLUSION

In this study it is demonstrated that Clark 63K and SCS1 have competent nutritional values as compared to expected nutritional composition of soybean products. In most cases, SCS1 performed better than Clark 63K. This shows that agricultural researchers and breeders are working in the right direction to improve the quality of soybean varieties. In addition to agronomical criteria, these findings can be used as input to national variety releasing body in decision making. Moreover, the current knowledge of the characteristics of soybean seeds, flours, and extrudates helps to identify suitable processing methods, design processing equipment's, selecting transportation, and storage and packaging technologies. Furthermore, the utilization of soy protein in many forms encourages consumers to use it as an alternative and comparatively cheaper protein source.

Acknowledgement

The authors appreciate the financial support and encouragement of the School of Chemical and Bioengineering of Addis Ababa University; and admire the assistance of Bahirdar University and Jimma Agricultural Research Center during the MSc thesis research.

5. REFERENCES

[1]. Alfonso Junior, P.C., Correa, P.C., Pinto, F.A.C., and Queiroz, D.M. (2007). Aerodynamic properties of coffee cherries and beans, Biosystems Engineering, 98, 39-46.

[2]. AOAC(2000). Approved Methods of the Association of Analytical Chemists, USA.

[3]. Berk, Z. (1992). Technology of production of edible flours and protein products from soy beans, FAO Agricultural service bulletin N0. 97, Israel. www.fao.org.

[4]. Beuchat, L.R.(1977). Functional and electrophoretic characteristics of succinylated peanut flour proteins, J. Agric.Food Chem. 25:258.

[5]. Bishnosi, S., and Khetarpaul, N. (1993). Effect of domestic processing and cooking method on in vitro starck digestibility of different pea cultivars (Pisum sativum). Food Chemistry, 48:177-182.

[6]. Brumm, T.J. (2006). Quality grading factors of IP Soybeans, Chapter two, Iowa state University, Accessed on August 25, 2008.

[7]. Chatziontonion, S., Triantafillou, D., and Thomaries, A.S. (2007). Functional properties of enzymatically hydrolyzed soy protein using Actinidin. International symposium on "Functional foods in Europe – international development in science and Health claims" 9-11 may, 2007, Malta.

[8]. Coffman, C.W. and Garcia, V.V. (1977). Functional properties and amino acid content of a protein isolate from mung bean flour. J. Food Technology, 12:473.

[9]. Darewicz, M., Dziuba, J., and Cessens, P. W.(2000). Effect of enzymatic hydrolysis on emulsifying and foaming properties of milk proteins. J. Food Nutr. Sci. 9(1): 3-8.

[10]. Edema, M.O., Lateef, O.S., and Abi odun, I.S.(2005). Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria, Agri. J. Biotechnol., 4:911-918.

[11]. El-Refai, A.A, Harras, H.M., El-Nemr, K.M., and Noaman, M.A.(1988). Chemical and Technological studies on Faba Bean seeds. I- Effect of storage on some physical and chemical properties.

[12]. Grahams, D.F. and Philips, M.C. (1996). Foams food Ankes, R. J. Acadamic press, London.

[13]. Li, H. and Burton, J.W. (2002). Selecting increased seed density to increase indirectly soybean seed protein concentration, accessed on September 2, 2008.

[14]. Okaka, J.C., and Potter, N. (1997). Physicochemical and functional properties of Cowpea powder processed to reduce beany flavour. J. Food Sci., 44: 1235-1240.

[15]. Onimawo, I.A., Momoh, A.H., and Usman, A. (1998). Proximate composition and functional properties of flour cultivars of Bambara groundnut (Voandezeia subterramean). Plant foods and Hum. Nutr. 53:153.

[16]. Williams P.C., Nakoul H. and Singh K.B. (1983). Relationship between cooking time and some physical characteristics in chickpeas (Cicer arietinum L.), J. Sci. Food Agric., 34:492-496.

[17]. Yasumatsu, K., Sawada, K., Moritakas, S., Misaki, M., Toda, J., Wada, T., and Ishii, K. (1972), Whipping and emulsifying properties of soybean products. Agriculture Biological Chemistry, 36:719.

[18]. Yimer, A. (2008). Effect of processing on some anti-nutritional factors of improved soya beans (Glycine max) varieties grown in Ethiopia, MSc thesis, AAU, Ethiopia

[19]. Yusuf, A.A, Folarin, O.M. and Bamiro, F.O. (2007). Chemical Composition and Functional Properties of gourd (Trichosanthes cucumerina) seed flour, Nigerian Food Journal, 25(1):36-45.

[20]. Yusuf, M.M. (1978). A study of factors affecting the cookability of faba beans (Vicia Faba L.), Ph. D. Thesis, College of Agricultural University of Alexandria, Egypt.