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Evaluation of chemical composition of improved and released soybean varieties in Ethiopia

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Soybean (Glycin Max) is one of the most important oil crops worldwide. Due to its high protein composition, it becomes the best choice to tackle protein malnutrition in developing countries, particularly for low income communities. This study was aimed to evaluate the chemical compositions of soybean varieties released in Ethiopia to generate baseline information for breeders, growers and nutritionists so that they will be able to choose the appropriate variety for their own purpose based on their chemical compositions. Seventeen (17) soybean varieties were used for this study and their proximate composition, amino acid and fatty acid compositions were determined according to the standard procedures. The protein and oil content of these varieties was found to be in the ranges of between 30.71% - 37.68% and 16.97%-22.86% respectively. Jalele was found to be significantly higher in protein content followed by Clarck63k and, in crud fat (oil content), Davice was found to be significantly higher among all varieties followed by AGS-7-1 and Belesa-95. All varieties were found to contain all of the essential amino acids Williams being the highest (14.15%) compared to other varieties. All varieties generally showed high level of unsaturated fatty acids with PUFA/SFA ratio between in the ranges of 2.89 (Nova) – 3.76 (Wegayen) which, in general, meets the requirement set by WHO/FAO to be greater than 0.4. The ω-6/ ω-3 ratio for all varieties ranges between 6.33 (Gishama) – 7.78 (Belesa-95) which may be a limiting factor for soybean nutrition and, thus, have to be combined with other food, rich in ω-3 fatty acids. Hence it can be concluded that the use of improved varieties with higher level of protein or unsaturated fatty acids can enhance the nutritional value of soy based food products.

Key words: Soybean, Nutrition, Varieties

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INTRODUCTION

Soybean (*Glycine max)* is one of the most important oil crops in the world which also is used as a good source of protein for the human diet (Masuda & Goldsmith, 2009). It is a cheap source of quality protein superior to other plant food staffs because it has good balance of the essential amino acids (Abioye et al., 2011). It is identical to all forms of animal protein and can be prepared in a variety of ways such as soy milk, powder, cakes, among others (Okolie & Ehiemere, 2009). Nutrition is fundamental to human life, health and development across the entire life

span. Proper food and good nutrition are essential for physical growth, mental development, performance and productivity, health and well-being (WHO, 2000). Consumers need to have whole host of qualities in their foods that include low cost, nutrition, health and taste (Krishnan & Darly-Kindelspire, 2013). Protein malnutrition is a global problem and more disastrous in developing countries (Okolie & Ehiemere, 2009). Currently, developing countries have focused on the improvement of protein quality of food products due to mass malnutrition (Abioye et al., 2011). Proteins are an essential component of the diet which provides adequate amount of amino acids (Friedman & Brandon, 2001).

Soy foods include cheese, drinks, miso, tempeh, tofu, salami, and vegetarian meat substitutes so that its consumption is increasing due to its nutritional benefits (Friedman & Brandon, 2001) and basis of human diets in many eastern countries due to its high nutritional value and low cost (Ciabotti et al., 2016). Soybean contains up to 42% protein (O'Keefe et al., 2015) and up to 22% oil, which is widely consumed as cooking oil (Friedman & Brandon, 2001). It provides all of the essential amino acids for humans and is one of the few legumes that can be consumed as complete protein (O'Keefe et al., 2015) protein.

Soybeans are associated to various health benefits such as anti-mutagenic effect, anti-inflammatory properties, reduction in synthesis of low-density lipoproteins and antioxidant properties (Ciabotti et al., 2016). The benefits also include lowering of plasma cholesterol, prevention of cancer, diabetes and obesity (Friedman & Brandon, 2001; Lokuruka, 2010). The American Heart Association recommends the intake of soybean-based products for patients with high cholesterol (Ciabotti et al., 2016). Soy products provide an excellent source of disease busting antioxidants, B vitamins (including folate) and iron which proves that soybean can promote heart health (Okolie & Ehiemere, 2009). Soybean seed contains some bioactive proteins such as *β*-amylase, cytochrome *c*, lectin, lipoxygenase, urease and the Kunitz inhibitor of trypsin (KTI). It also provides some biologically active secondary metabolites such as isoflavones, saponins, phytic acid, flatus-producing oligosaccharides, and goitrogens (Friedman & Brandon, 2001). Soy isoflavones appears to result in health benefits for cancer, heart disease, menopausal symptoms and osteoporosis (Bolla, 2015). Soybean oil is known for its high unsaturated fatty acid content which is associated to lower risk of cardiovascular disease (O'Keefe et al., 2015). In contrast saturated fatty acids (SFA) are responsible for cause of cancers and coronary heart disease. Hence WHO/FAO recommend the mean PUFA/SFA ratio to be 0.4 and above and the British health department sets PUFA/SFA ratio to be 0.45 and above (Ivanov et al., 2010) to indicate that good nutrition should contain high level of unsaturated fatty acids. Studies showed that, soybean has small amounts of saturated fatty acid and it is cholesterol free (Ciabotti et al., 2016). Soybean is especially interesting due to its non-gluten proteins (Ivanov et al., 2010). Thus, due to its health benefits, supermarkets in developed countries are displaying soy food products in various forms (Lokuruka, 2010).

Currently, United States is the largest producer of soybean in the world making up 35% of the total production and it becomes one of the most important economic crops in the nation and Brazil, Argentina and China following the production rates (He & Chen, 2013). However, besides the potential use of soybean to address nutrition and food insecurity problems, little emphasis has given for its production, supply and export to this important crops so far (Hailu & Kelemu, 2014). Food insecurity and malnutrition problem is relatively more serious in rural than urban areas of Ethiopia, mainly because of a low level of understanding of a balanced diet and lack of capacity to purchase animal source proteins (Hailu & Kelemu, 2014). Lack of knowledge on how to locally process food products from soybean and market problem of the crop also leads the farmers to carelessly engage on the production of the crop (Bekabil, 2015). The level of chemical constituents including the essential component of food, protein, is influenced by a number of environmental and genetic factors (Ciabotti et al., 2016). Soybean chemical compositions, too, vary depending on variety, location, climate and farming practices (He & Chen, 2013). The knowledge of chemical compositions helps to understand and focus on the nutritional impact of agricultural commodities. So far, until 2015, a total of 25 improved soybean varieties were released in Ethiopia (MoANR, 2016) mainly with adaptability area, yield, disease and pest resistance merits. But, as nutrition quality matters, nutritional composition should also need to be emphasized in the variety improvement research, food processing and blending. However, chemical composition of soybean varieties released in Ethiopia are not evaluated and well documented. Thus, the objective of this study was to determine and evaluate chemical composition of improved and released soybean varieties in Ethiopia to generate baseline information to help local growers, breeders, nutritionist, dietitians and food processing industries in the selection of the appropriate variety for cultivation and food processing from nutritional aspect.

MATERIALS AND METHODS

In this study a total of seventeen (17) soybean varieties were used. The soybean samples were collected from Ethiopian Institute of Agricultural Research (EIAR), Pawe Agricultural Research Center in 2015. The samples collected were brought to Ethiopian Institute of

Agricultural Research, Agricultural Quality Research Laboratory. Following the standard procedures the sample were prepared and stored in paper bags for further analysis.

Proximate composition

The samples obtained were analyzed for proximate composition such as moisture, ash, crude fibre, and crude fat according to AOAC methods (AOAC, 2005). Protein was analyzed according to kjeldahl methods described by Foss analytical AB (Foss analytical AB, 2003). Carbohydrate content was calculated by the difference [100-(protein + crude fat + ash + fibre + moisture)] (Ciabotti et al., 2016).

Amino acid and Fatty acid composition

The amino acid and Fatty acid composition of soybeans were analyzed at INVIVO labs Vietnam. High performance liquid chromatography (HPLC) was used for the amino acid analysis following the standard methods of AOAC (AOAC, 2012) method 999.13:2012. Gas chromatography (GC) was used for Fatty acid analysis following the standard procedures of ISO (ISO, 2000) method 5508/5509:2000(V).

Statistical analysis

Data for proximate compositions were analyzed by one way ANOVA (Duncan's multiple range test) using SAS software (Version 9.0) to see significant differences between varieties in each parameters and the result was expressed as mean ± SD (standard deviation).

RESULTS AND DISCUSSIONS

A. Proximate composition

The percentage proximate composition of soybean varieties considered in this study is presented in Table 1 and simple comparison is shown in Figure 1. In this study, soybean of all varieties was found to contain protein content of 30.71% - 37.68% and oil content of between 16.97%-22.86%. Generally, in both parameters, the result is in close consistence to previous reports besides the fact that there will be difference between varieties, location and agronomic practices. Compared to all varieties, considered in the study, Jalele was found to contain the maximum protein content (37.68%) and it was significantly different from other varieties in protein content followed by clarck63k (37.35%). The maximum oil content (crude fat) was recorded in Davice (22. 86%) and differ significantly to all varieties followed by AGS 7-1 (22.15%) and Belesa-95 (22.00%) with no significant difference the two later varieties. Afgat was found to contain the minimum oil content (16.97%) among all varieties considered in the study. Proximate analysis is the first step in the chemical evaluation of feed ingredients as it helps the nutritionist to draw a primary decision on the quality of raw material and how they can influence the final food quality standards (Masagounder et al., 2016). As soybean is basically needed for its oil and protein content worldwide (Masuda and Goldsmith, 2009) the quality of these parameters are of great interest in soybeans. Soybean, generally, has reported to contain protein content of 37%-42 ((Ivanov et al., 2010; O'Keefe et al., 2015) and oil content of up to 22% ((Friedman & Brandon, 2001). Soybean has also recognized to have good source of dietary fibre, mainly of the soluble type which contains up to 6% crude fibre (Banaszkiewicz, 2011). The crude fibre for soybean varieties considered in this study was found to be between 5.69-8.69% which is in consistent to the previous results and can be concluded generally that soybean is good source of fibre.

B. Amino acid composition

Amino acid composition of soybean varieties considered in this study is presented in Table 2. As it is indicated in the result, Table 2, soybean were found to contain all of these essential amino acids namely Phenylalanine, Valine, Threonine, Tryptophan, Methionine, Leucine, Isoleucine, Lysine and Histidine which is also supported by previous reports in which soybean is recognized to provide a complete protein, all of the essential amino acids, and it is one of the few legumes that provide these

essential amino acids (O'Keefe et al., 2015). In terms of total amino acid composition, Williams showed higher amount of total amino acids (36.66%) and it is also found to provide higher amount of essential amino acids (14.15%) compared to other varieties and Gazale showed the minimum amount of total amino acid (30.11%), and also has the least essential amino acid content (11.64%).

C. Fatty acid profile

A fatty acid profile of improved and released soybean varieties in Ethiopia is presented in Table 3. All soybean varieties considered in this study, generally, showed higher amount of unsaturated fatty acids with PUFA/SFA ratio of between 2.89 (Nova)-3.76 (Wogayen) which meets the requirement set for PUFA/SFA ratio by WHO/FAO to be 0.4 and above. The presence of high level of unsaturated fatty acids is attributed to the lower risk of cardiovascular disease (O'Keefe et al., 2015) and, in contrast, saturated fatty acids are causes of cancers

Table 1: Proximate composition of improved and released soybean varieties in Ethiopia (%)

Variety name	Moisture	Ash	Crude fat	Crude protein	Crude fibre	Carbohydrate
Clark63k	7.56 ± 0.01^{ed}	4.33 ± 0.03^{g}	19.89 ± 0.12^{fg}	37.35 ± 0.41^{b}	7.27 ± 0.26^{dc}	23.61 ± 0.29^{gf}
Nyala	7.53 ± 0.07^{ed}	4.16 ± 0.07^{h}	19.87 ± 0.36^{fg}	33.40 ± 0.14^{i}	8.69 ±0.15^{a}	26.35 ± 0.20^{c}
Awasa-95	8.08 ± 0.01^{a}	4.87 ± 0.01^{a}	19.10 ± 0.07^{h}	35.10 ± 0.06^{hg}	7.47 ± 0.16^{c}	25.39 ± 0.04^{d}
Gishama	7.75 ± 0.07^{dc}	4.04 ± 0.04^{j}	19.47 ± 0.66^{hg}	32.87 ± 0.2^{k}	7.44 ± 0.21^{c}	28.44 ± 1.1^{b}
Nova	7.48 ± 0.08^{e}	4.58 ± 0.01^{dc}	20.91 ± 0.43^{dc}	36.71 ± 0.2^{c}	6.26 ± 0.11^{hg}	24.06 ± 0.28^{ef}
Gizo	7.77 ± 0.09^{bdc}	4.51 ± 0.04^{fe}	18.98 ± 0.06^{h}	36.18 ± 0.2^{d}	7.30 ± 0.08^{dc}	25.26± 0.18^{d}
Davice	7.49 ± 0.28^{e}	4.60 ± 0.04^{c}	22.86 ± 0.14^{a}	36.41 ± 0.11^{dc}	7.53 ± 0.2^{c}	21.11 ± 0.77^{h}
Williams	7.92 ± 0.05^{bac}	4.71 ± 0.01^{b}	21.33 ± 0.15^{c}	35.28 ± 0.04^{fg}	8.17 ± 0.38^{b}	22.61 ± 0.52^{g}
Boshe	7.18 ± 0.02^{f}	4.20 ± 0.04^{h}	21.28 ± 0.11^{c}	33.12 ± 0.23^{jik}	6.20 ± 0.1^{hi}	28.01 ± 0.38^{b}
Tgx-13.3-2644	7.85 ± 0.13^{bac}	4.50 ± 0.01^{f}	21.05 ± 0.21^{dc}	33.26 ± 0.01^{jl}	6.63 ± 0.12^{fg}	26.72 ± 0.22^{c}
Afgat	7.77 ± 0.22^{bdc}	4.52 ± 0.01^{fe}	16.97 ± 0.18^{i}	35.61 ± 0.03^{e}	7.00 ± 0.27^{de}	28.13 ± 0.22^{b}
Crowford	7.37 ± 0.04^{ef}	4.49 ± 0.02^{f}	20.71 ± 0.11^{de}	36.47 ± 0.17^{dc}	5.88 ± 0.35^{jl}	25.09 ± 0.64^{d}
Wegayen	7.38 ± 0.31^{ef}	4.51 ± 0.03^{f}	20.22 ± 0.78^{fe}	35.46 ± 0.18^{fe}	5.69 ± 0.19^{j}	26.74 ± 1.47^{c}
Belesa-95	6.88 ± 0.12^{g}	4.19 ± 0.02^{h}	22.00 ± 0.04^{b}	33.03 ± 0.20^{jk}	7.01 ± 0.25^{de}	26.88 ± 0.36^{c}
AGS-7-1	7.21 ± 0.22^{f}	4.54 ± 0.02^{dfe}	22.15 ± 0.29^{b}	34.93 ± 0.18^{h}	6.37 ± 0.1^{hg}	24.79 ± 0.01^{ed}
Gazale	8.05 ± 0.03^{a}	4.11 ±0.01^{i}	20.63 ± 0.28^{de}	30.71 ± 0.15^{l}	6.83 ± 0.2^{fe}	29.67 ± 0.65^{a}
Jalele	8.00 ± 0.06ba	4.56 ± 0.01^{dce}	19.83 ± 0.07^{fg}	37.68 ± 0.03^{a}	6.61 ± 0.12^{fg}	23.31 ± 0.1^{gf}
Mean	7.61 ± 0.34	4.44 ± 0.23	20.43 ± 1.4	34.92 ± 1.90	6.96 ± 0.79	25.66 ± 2.28
C.V. %	1.82	0.64	1.53	0.51	3.00	2.25

Means with the same letters of superscript in the same column did not differ significantly ($p < 0.05$).

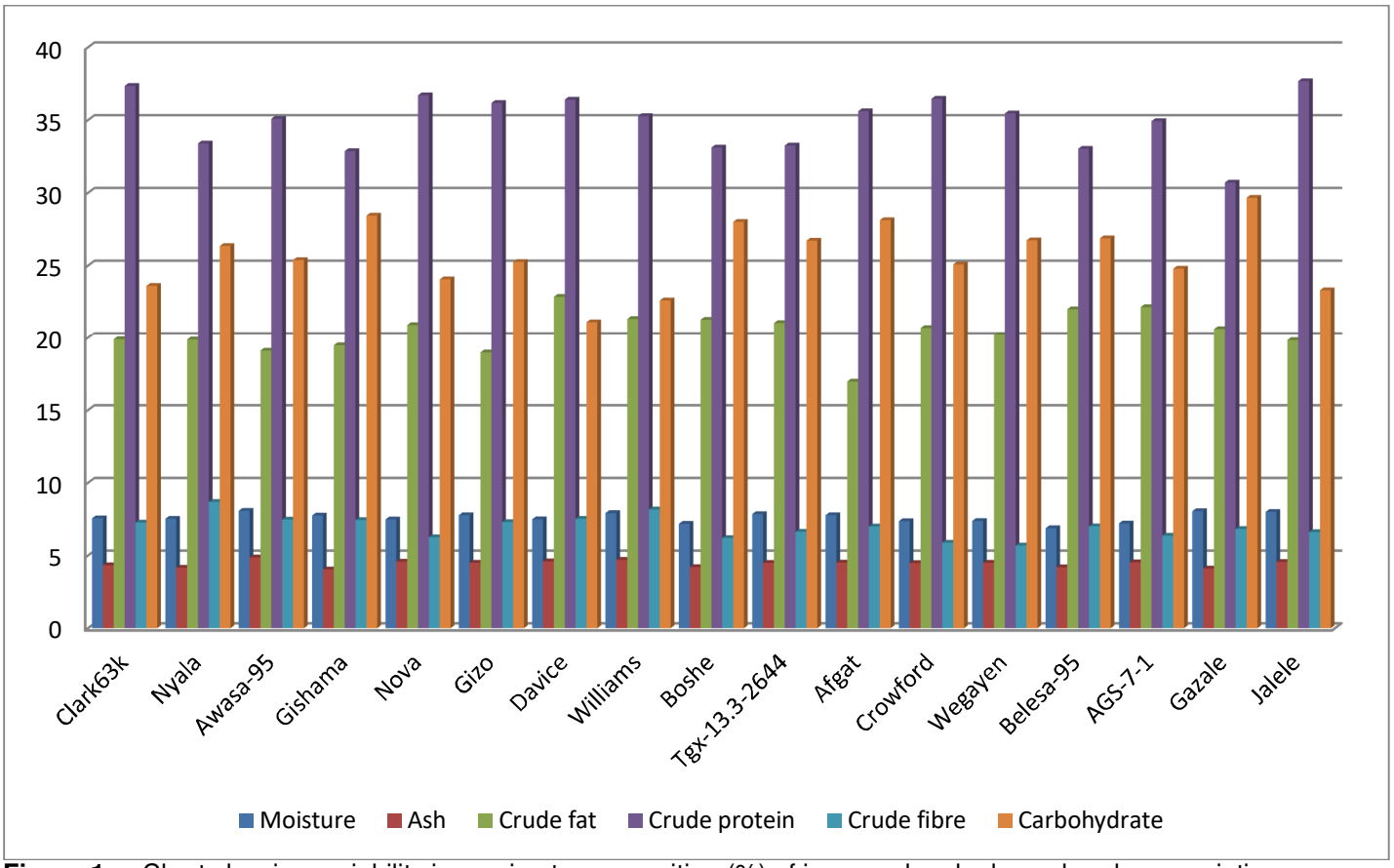

Figure 1: a Chart showing variability in proximate composition (%) of improved and released soybean varieties

Table 2: Amino acid composition of improved and released soybean varieties in Ethiopia (%)

Variety name	Aspartic acid	Serine	Glutamin acid	Glycine	Histidine*	Arginine	Threonine*	Alanine	Proline	Cystine	Tyrosine	Valine*	Methionine*	Lysine*	Isoleucine*	Leucine*	Phenyl Alanine*	Tryptophan*	Total Amino
Clarck63k	3.96	1.76	6.33	1.49	0.95	2.51	1.37	1.44	1.82	0.45	1.25	1.70	0.46	2.23	1.68	2.70	1.86	0.5	34.46
Nyala	3.91	1.77	6.12	1.52	0.99	2.51	1.37	1.38	1.70	0.50	1.28	1.72	0.40	2.14	1.67	2.62	1.80	0.47	33.87
Awasa-95	4.02	1.80	6.37	1.57	0.98	2.53	1.40	1.43	1.76	0.58	1.28	1.74	0.44	2.18	1.65	2.56	1.80	0.5	34.59
Gishama	3.85	1.79	6.09	1.54	0.96	2.50	1.40	1.37	1.67	0.47	1.29	1.67	0.49	2.15	1.62	2.58	1.78	0.5	33.72
Nova	4.04	1.93	6.56	1.64	1.01	2.65	1.45	1.46	1.91	0.62	1.34	1.71	0.49	2.24	1.66	2.70	1.89	0.49	35.79
Gizo	3.67	1.83	5.99	1.59	1.01	2.59	1.40	1.39	1.77	0.49	1.31	1.66	0.42	2.08	1.62	2.60	1.83	0.51	33.76
Davice	4.12	1.89	6.75	1.60	0.98	2.72	1.34	1.46	1.89	0.55	1.33	1.76	0.47	2.23	1.72	2.71	1.91	0.48	35.91
Williams	4.29	1.92	6.78	1.66	1.03	2.67	1.49	1.48	1.88	0.51	1.32	1.83	0.46	2.31	1.79	2.78	1.92	0.54	36.66
Boshe	3.73	1.71	5.94	1.45	0.91	2.35	1.33	1.35	1.65	0.46	1.19	1.62	0.48	2.08	1.57	2.46	1.69	0.49	32.46
Tgx-13.3-2644	3.94	1.73	6.20	1.51	0.95	2.45	1.36	1.38	1.63	0.53	1.27	1.68	0.42	2.17	1.63	2.55	1.72	0.5	33.62
Afgat	4.24	1.85	6.64	1.62	1.04	2.68	1.38	1.48	1.82	0.46	1.32	1.79	0.46	2.23	1.71	2.71	1.85	0.52	35.80
Crowford	3.82	1.83	6.26	1.62	1.02	2.76	1.31	1.40	1.81	0.46	1.36	1.78	0.46	2.14	1.72	2.70	1.94	0.47	34.88
Wegayen	4.12	1.86	6.53	1.58	0.99	2.58	1.42	1.43	1.78	0.51	1.31	1.72	0.40	2.23	1.68	2.64	1.80	0.48	35.06
Belesa-95	3.92	1.73	6.00	1.46	0.97	2.35	1.35	1.37	1.63	0.44	1.24	1.62	0.41	2.08	1.56	2.49	1.69	0.46	32.77
AGS-7-1	4.02	1.85	6.54	1.54	0.96	2.55	1.40	1.39	1.76	0.53	1.31	1.65	0.46	2.20	1.64	2.64	1.84	0.49	34.77
Gazale	3.55	1.59	5.52	1.34	0.91	2.11	1.25	1.28	1.52	0.42	1.14	1.46	0.35	1.91	1.45	2.26	1.61	0.44	30.11
Jalele	4.09	1.85	6.56	1.59	1.02	2.68	1.42	1.45	1.84	0.47	1.31	1.79	0.41	2.18	1.70	2.67	1.90	0.51	35.44

*Essential amino acids

Table 3: Fatty acid composition of improved and released soybean varieties in Ethiopia (mg/100g)

Variety name	Total omega-3	Total omega-6	Total trans-fat	Total satu.fat	Total MUFA	Total PUFA	Total FA	PUFA/SFA ratio
Clarck63k	1516.8	11300.1	10.9	3741.6	5222.2	12860.1	21823.9	3.44
Nyala	1709.8	11061.0	30.5	3906.7	4979.8	12841.8	21728.2	3.29
Awasa-95	1764.5	11179.2	10.6	3856.2	4256.3	12979.1	21091.7	3.37
Gishama	1641.3	10398.3	10.7	3609.0	5781.8	12054.4	21445.2	3.34
Nova	1524.3	9988.1	15.5	3990.6	6517.4	11547.2	22055.3	2.89
Gizo	1453.0	9276.5	0.0	3366.5	5701.9	10739.2	19807.6	3.19
Davice	1446.3	11211.9	13.3	3686.0	5721.0	12717.5	22124.5	3.45
Williams	1519.1	10479.0	76.8	3660.4	5581.8	12067.4	21309.7	3.30
Boshe	1894.9	12516.3	11.3	3937.7	4227.3	14424.5	22589.6	3.66
TgX-13.3-2644	1905.0	12099.7	13.5	3792.7	4558.0	14017.9	22368.6	3.70

Table 3: Continuation

Afgat	1330.1	8576.8	0.0	3367.9	5935.0	9916.4	19219.3	2.94
Crowford	1502.7	10602.7	10.7	3591.8	5669.6	12105.3	21366.8	3.37
Wegayen	1555.8	11846.4	0.0	3567.4	4999.7	13423.9	21991.0	3.76
Belesa-95	1531.1	11924.2	15.7	3763.2	5153.7	13477.4	22394.2	3.58
AGS-7-1	1582.1	11783.5	11.2	3747.3	5213.9	13378.8	22340.1	3.57
Gazale	1621.0	11326.0	0.0	3858.4	4664.4	12961.8	21484.5	3.36
Jalele	1433.5	9585.3	11.3	3390.5	4385.5	11070.7	18846.7	3.27

MUFA= Mono unsaturated fatty acid, PUFA=Polyunsaturated fatty acid

and other heart disease (Ivanov et al., 2010). Wogayen were found to contain relatively higher PUFA/SFA ratio (3.76) compared to other all varieties. The ratio of ω-6/ ω-3 for all varieties were found to be between 6.33 (Gishama) -7.78 (Belesa-95) which is, in general, above the maximum requirement. A study suggested ω-6/ ω-3 ratio to be less than 4 due to the fact that ω-3 fatty acids have benefits related to cancer, inflammatory bowel disease rheumatoid arthritis, and psoriasis (Ivanov et al., 2010). This may be, in general, a limiting factor for soybean nutrition. Most western diet also has this problem due to the fact that it contains low ω-3 fatty acids and very high ω-6 fatty acid content (Ivanov et al., 2010). From this result it should be noted that soybean may not be used as the only source of fatty acids in human nutrition and have to be combined with other food, rich in ω-3 fatty acids.

CONCLUSIONS

As soybean is recognized worldwide particularly for its protein and oil content, yield and quality of the two parameters is of great importance for soybean quality. The result showed that there is significant difference in the chemical composition of soybean varieties. Thus, it can be concluded that the use of improved soybean variety with high protein or oil content can enhance the nutritional value of soy based food products. Hence, nutritionist, growers and food processing industries are recommended to spur the use of soybean variety having significantly higher protein content. The higher ω-6/ ω-3 ratio is a limiting factor for soybean nutrition and, thus, it may not be the only source of ω-3 fatty acids and, hence, soybeans have to be combined with other food, rich in ω-3 fatty acids.

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ABBREVIATIONS

AOAC	Association of Official analytical chemists
C.V	Coefficient of Variation
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture organization
ISO	International Organization for Standardization
MoANR	Ministry of Agriculture and Natural resources
PUFA	Polyunsaturated fatty acids
SD	Standard Deviation
SFA	Saturated fatty acids
WHO	World Health Organization

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