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Effect of chick pea level and feed moisture content on physical properties of teff flour extrudates

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Abstract

Effect of chick pea level (0-30%) and feed moisture content (12% and 14% wb) on physical properties of extruded product from teff [*Eragrostis teff* (Zucc.) Trotter] (CR-387 variety) and chick pea (*Cicer arietinum* L.) (*marye* variety) were investigated. Chick pea level showed more effect on physical properties of products than feed moisture content. Increased level of chick pea resulted in increased bulk density and water solubility index (WSI) and decreased diametric expansion ratio and sensory crispness. On the other hand, lower feed moisture resulted in higher WSI. Sensory analysis for crispness revealed that the most accepted product had a mean score of 3.93 (on 5-point rating scale) and was produced from 10% chick pea blend at 14% feed moisture. The mean values of diametric expansion ratio, bulk density, WAI and WSI of this product were 1.58, 127.5 kg m^{-3}, 5.7g g^{-1} and 30.92%, respectively. Thus twin screw extrusion of teff flour blended with 10% chick pea flour would produce an acceptable snack enhanced by protein.

Introduction

According to the national estimates of the Central Statistics Authority (CSA, 2012), teff, [*Eragrostis teff* (Zucc.) Trotter], accounts for about 16% of the gross grain production of all the cereals cultivated in Ethiopia covering about 2.7 million hectares of land in 2011/12. Because teff is predominantly grown in Ethiopia as a cereal crop and its cultivation as a cereal grown for food is little known elsewhere in the world, its primary processing is mainly limited to indigenous processing to make injera, pancake-like fluffy soft bread, which is staple food for most Ethiopians (Bultosa, 2007; Kebede *et al*., 2010). The grain is also used to make local alcoholic drinks, called tela and katikala (Bultosa, 2007). Teff contains more lysine than barley, millet, and wheat and slightly less than rice or oats (Piccinin, 2002). Teff grain is gluten-free, and is gaining popularity as an alternative grain for persons with gluten sensitivity (Bultosa, 2007).

Chick pea protein contains significant amounts of all the essential amino acids except sulphur containing types. Chick pea is also rich in nutritionally important unsaturated fatty acids like linoleic and oleic acid (Jukanti *et al*., 2012). Further, there is a growing demand for chickpea due to its high potential as a functional ingredient for the food industry (Deshpande and Poshadri, 2011; Jukanti *et al*., 2012). Extrusion of the blend of teff and chick pea could increase nutrient and energy density. Besides to nutrition merits, extrusion of the blend could be considered as a value addition strategy for both food crops which are usually traditionally processed in Ethiopia. Ethiopia is among the major chickpea producing countries (Jukanti *et al*., 2012).

Kebede *et al*. (2010) investigated the effect of extruder operating conditions on the physical and sensory properties of teff flour extrudates and ascertained the potential of teff for producing extrusion cooked products. Extrusion cooking of a mixture of teff flour, corn flour and soy protein isolates was also conducted as protein enrichment strategy (Forsido & Ramaswamy, 2011). Successful cereal-legume composites extrusion has been reported (Chakraborty and Banerjee, 2009; De Mesa *et al*. 2009; Deshpande and Poshadri, 2011). A big proportion of breakfast cereal and a variety of crispy/crunchy snacks are produced by extrusion, which is an important and widely used processing technology (Cheng *et al*., 2007).

The composition of the feed material influences viscosity which is a crucial factor that determines the operating conditions of the extruder and hence product quality (Moraru and Kokini, 2003). Extruder operating conditions have also been indicated to affect product quality during extrusion of such products (Ding *et al*., 2006; Chakraborty and Banergee, 2009; Kebede *et al*., 2010). Taking in to account the potential of teff as an important starch-rich cereal to

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produce new products coupled with the possibility of supplementing with protein-rich chick pea, this work was conducted to investigate the effect of chick pea level and feed moisture content on physical property of teff flour extrudates.

Materials and Methods

Raw material preparation

Teff grain, CR-387 (locally known as *kuncho* variety), and chick pea, *marye* variety, harvested in 2011/2012 production year, were collected from Adet Agricultural Research Center, Ethiopia. Teff grain was cleaned and milled into flour using commercial mill. Following grinding, the flour was sifted to pass through 710 µm test sieve (Kebede *et al*., 2010). The chick pea was cleaned, dehulled and sifted. Then the flake was milled using commercial mill and the flour was then sifted to pass through 710 µm test sieve to achieve uniform particle size with the teff flour. The flour of both teff and chick pea was analyzed for proximate composition (moisture content, crude protein, crude fat, and total ash) according to Association of Official Analytical Chemists (AOAC, 2005). The teff and chick pea flour was mixed based on the required level and stored at room temperature for a week before extrusion to condition the feed moisture content.

Experimental design and extrusion experiment

A 4×2 full factorial experiment comprising of four levels of chick pea level (0-30%) and two levels of feed moisture content (12% and 14% wb) were used to produce extruded snack. Extrusion was conducted on a pilot scale co-rotating twin screw food extruder (Model Clextral, BC-21 No 124, Firminy, France) using a die of 9 mm size. The barrel has a smooth 300 mm useful length and consists of three modules each 100 mm long fitted with 25 mm diameter screws. Each zone-temperature is controlled by a Eurotherm controller (Eurotherm Ltd. Worthing, UK). Twin screw volumetric feeder (type KMV- KT20) delivers the raw material into the extruder inlet. While operating, water at ambient temperature was injected into the extruder via an inlet port by a positive displacement pump (DKM-Clextral, France). The barrel temperature was fixed in zone 2 at 70ºC and zone 3 at 130ºC (±2ºC). The moisture content of the feed was adjusted by varying the water injection rate of the pump. Both the feeder and the pump were calibrated prior to the extrusion in order to avoid fluctuations during the operation. The pump was adjusted to give a moisture content of 12 and 14% (wb) in the mixes for a constant material feed rate of 9 kg h^{-1} by using hydration Equation (Eq. 1) (Golob, 2002; Kebede *et al*., 2010). The selected feed moisture was estimated based on several preliminary experiments.

$$W_a = S_w \times \left(\frac{m - m_o}{100 - m}\right) \quad (1)$$

Where:
W_a = weight of water added (g), S_w = is sample flour weight (g); m_o= original flour moisture content (% wwb), and m = required dough moisture level in (% wwb).

Determination of product properties

During extrusion, samples were extruded as straight rope and extruded samples were collected when the extrusion process parameters reach steady state. Straight extrudates were manually cut to a uniform length of about 2 cm to calculate the physical properties. The extruded products were placed on a table and allowed to cool for 30 minutes at room temperature for the measurement of weight and diameter, according to Kebede *et al*., (2010). The other samples were sealed in plastic bags (after equilibrated for 24 hr at ambient condition) and stored at room temperature to measure water absorption index and water solubility index.

Diametric expansion ratio

Length and diameter of the extrudates were measured by a digital vernier caliper having 0.01 mm accuracy (СДЕЛАНО, ссср, Russia). Weight was measured on a balance of 0.1 mg sensitivity (AAA250L, Adam Equipment Co. Ltd, UK). A mean value of length, weight and diameter from at least 4 measurements were recorded for each experimental run. The diametric expansion ratio, which is defined as the ratio of the diameter of the extrudate to the diameter of the die hole (Mason and Hoseney, 1986) was calculated as follows (Eq. 2).

$$D_r = \left(\frac{D_e}{D_d}\right) \quad (2)$$

Where: D_r is diametric expansion ratio, D_e is diameter of extrudates in cm and D_d is diameter of die whole in cm

Bulk density

Based on the measurements of weight, length and diameter as described above, the bulk density of the extrudates was calculated as in Eq. (3) (Mason and

Hoseney, 1986; De Mesa *et al.*, 2009; Kebede *et al.*, 2010).

$$\rho = \frac{4w}{\pi D_e^{\,2} \times L_e} \quad (3)$$

Where:

ρ = bulk density (g cm^{-3}), D_e= diameter of extrudates (cm), L_e= length of extrudate (cm) and w = weight of extrudate (g). The diameter and length units were converted to metre (m) and weight unit were converted to kg to calculate the density in kg m^{-3}.

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

WAI and WSI of extrudates were determined according to Anderson *et al.* (1969). Sample (about 1.25 g) was placed in about 40 ml centrifuge tube and suspended in 30 ml distilled water. The sample was incubated into constant temperature stirred water bath (CU 420, Electric heat constant temperature water box, China) at 25°C for 30 minutes and was centrifuged at 3000 g for 5 minutes. Mass of the sample was determined before and after decantation of the clear supernatant of the centrifugation. The WAI was calculated as grams of adsorbed water per gram of dry sample mass (Eq. 4). The supernatant preserved from WAI measurement was transferred into pre-dried and weighed glass beaker and then evaporated at 105°C for overnight in a drying oven. The WSI was calculated as a ratio of dry residue (W_r) to the original mass used to estimate WAI (W_o). The result was expressed as percentage.

$$WAI = \frac{W_s}{W_o} \quad (4)$$

$$WSI = \frac{W_r}{W_o} \times 100 \quad (5)$$

Where: W_s - weight of sediment (g) and W_o -weight of sample (g)

Product crispness

Fifteen judges were selected from the staff and undergraduate class students of Food Technology and Food Process Engineering programme of Bahir Dar University. The sensory attribute- crispness was analysed using rating scale 1 (no crispy) to 5 (very crispy). Coded product samples were arranged in a random order on white plates and served to the sensory judges. Just before the test session, orientation was given to the judges.

Statistical data analysis

Analysis of variance was carried out to investigate the effect of chick pea level and feed moisture content on product properties using SPSS 16. Significance was judged by determining the probability level that the F-statistic calculated from the data was less than 5%. Mean separation was carried out using LSD.

Results and Discussion

Proximate composition of raw materials

The mean values of moisture, protein, crude fat and ash content of teff and dehulled chick pea flour were 12.60 and 8.73, 8.49 and 17.65, 2.77 and 7.52 and 2.41 and 3.17, respectively, all showing significant difference except ash content. As expected, the crude protein and crude fat composition of dehulled chick pea flour was significantly higher than teff flour ($p<0.05$). The proximate composition of the teff flour is in agreement with the literature except for its lower crude protein content. Bultosa (2007) analysed proximate composition of 13 teff varieties grown in Ethiopia and reported that the protein ranges from 8.7-11.1%, ash 1.99-3.16% and crude fat 2.0-3.0% for moisture ranges from 9.3-11.22%. Kebede *et al.* (2010) and Sadik *et al*. (2013) reported similar results with this study with slight variations. The higher moisture content in this study which is in agreement with Kebede *et al.* (2010) could be due to field drying practices commonly used in Ethiopia. The lower protein content in this study could be attributed to the higher moisture content of the flour and agronomic practices used during agricultural production.

Diametric expansion ratio

The effect of chick pea level and feed moisture on diametric expansion of extrudates is shown in Figure 1.

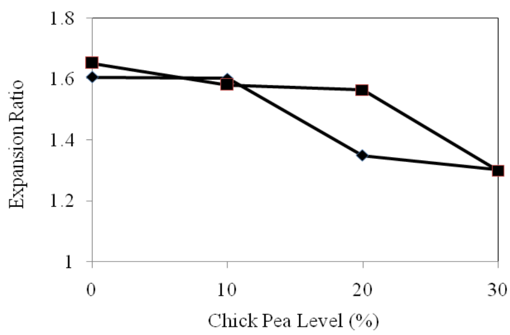

Figure 1. Effect of chick pea level on diametric expansion of products extruded at 12% (▲) and 14% (■) feed moisture content

Chick pea level had significant effect on diametric expansion of extrudates ($P<0.05$) while the effect of feed moisture content was not statistically significant. Increasing chick pea level resulted in reduction of expansion for all the chick pea levels

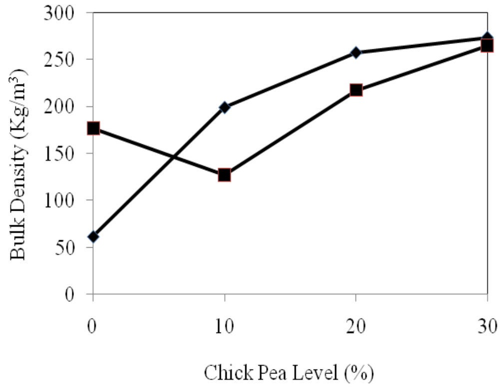

Figure 2. Effect of chick pea level on bulk density of products extruded at 5 % (▲) and 10% (■) feed moisture content

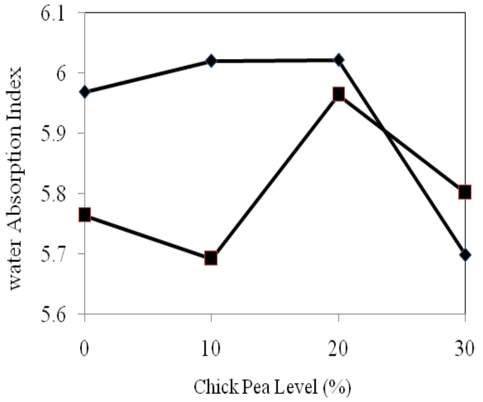

Figure 3. Effect of chick pea level on WAI of products extruded at 12% (▲) and 14% (■) feed moisture content

used. Substitution of 20% and 30% chick pea flour to teff flour resulted in extrudates that had significantly lower expansion than the control (0%) while 30% chick pea flour substitution showed significantly lower expansion than 10%. Expansion of extrudates produced from 10% chick pea flour substitution had lower expansion than the control, though the difference was statistically insignificant. This result is in agreement with Suksomboon *et al*. (2011) and Pelembe *et al*. (2002) who reported that blending higher proportion of chick pea flour to purple rice flour and cow pea flour to sorghum flour respectively, resulted in lower expansion of blend extrudates. De Mesa *et al*. (2009) also reported increasingly lower expansion of maize starch extrudates with the addition of 0-20% soy protein concentrate and associated the phenomenon with starch-soy protein concentrate interactions affecting the expansion indirectly by system mechanical energy and directly by disrupting the continuous starch matrix which reduces extensibility of cell walls. Similar effect might have contributed to the reduction of expansion at higher chick pea levels. Further, the increase in lipid content of the blend at higher chick pea level could also contribute to the reduction in expansion. Chinnaswamy and Hanna (1988) indicated that the expanded volume of cereal flour decreases with increasing amounts of protein and lipid. Oils and fats provide a powerful effect on lubrication effect in the compressed polymer mix during extrusion (Ilo *et al*., 2000).

Bulk density

The effect of chick pea level and feed moisture on bulk density of extrudates is shown in Figure 2. Higher level of chick pea flour resulted in higher bulk density. This could be because of lower expansion at higher level of chick pea (Figure 1) which could also be explained by the negative association of bulk density with expansion ratio ($r = -0.67$, $P<0.05$). Suksomboon *et al.* (2011) reported similar result while extruding purple rice flour blended with 5-15% soybean. Statistically significant difference ($p<0.05$) was observed among extrudate bulk densities produced with all the chick pea levels used except 20% and 30%.

As can be seen from figure 2, products extruded at higher feed moisture (14%) had lower density for all the chick pea levels used except for the control, though the difference was not statistically significant. On the other hand, the interaction of feed moisture and chick pea level had significant ($p<0.05$) effect on bulk density. Maximum mean bulk density of 273.7 kg m^{-3} was observed for extrudates produced with 30% chick pea level extruded at 12% feed moisture while the minimum mean bulk density of 61.3 kg m^{-3} was observed for the control at 12% feed moisture.

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

Gelatinization which leads to transformation of raw starches to a cooked digestible material is one of the important effects that extrusion has on starch component of foods. Higher WSI indicates starch has been dextrinzed (De Mesa, 2009; Kebede *et al*., 2010). In this study, neither of the factors nor their interaction had significant effect on WAI of extrudates ($P>0.05$) (Figure 3). Despite this, chick pea level, feed moisture and their interaction had significant effect on WSI. WSI showed reducing trend with increasing chick pea level, and the differences were statistically significant except for extrudates produced at 10% chick pea level and the control.

Both increasing and decreasing trends of WSI with blended legume level exist in the literature. Extruding corn and soybean protein concentrate (SPC) blend, De Mesa *et al*. (2009) found out that WSI decreased with increase in SPC level. Singh *et al*. (2007) concluded the same when investigating

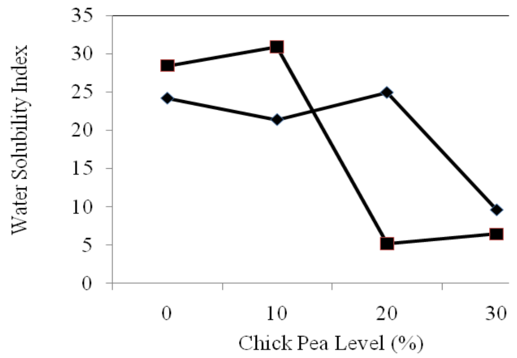

Figure 4. Effect of chick pea level on WSI of products extruded at 12% (▲) and 14% (■) feed moisture content

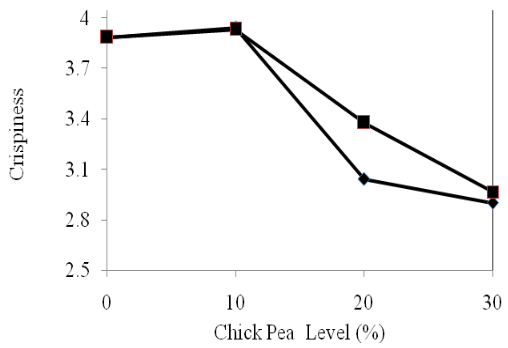

Figure 5. Effect of chick pea level on crispness of products extruded at 12% (▲) and 14% (■) feed moisture content

the effect of addition of pea grits on rice flour during extrusion. Chang *et al*. (2001) also reported lower WSI with increasing levels of SPC in cassava starch-SPC blend extrusion. Other researchers reported the opposite. WSI increased with cowpea proportion during sorghum and cowpeas blend extrusion (Pelembe *et al*., 2002). WSI was also reported to increase with increase in soybean proportion in African bread fruit, yellow corn and defatted soybean flour extrudates (Nwabueze, 2006). Extrusion is known to decrease protein solubility, which has been related to the formation of insoluble aggregates, involving both covalent disulfide bonds and non-covalent interactions (Liu and Hsieh, 2008). Oils and fats provide a powerful lubrificant effect in the compressed polymer mix during extrusion cooking (Ilo *et al*., 2000) which further negatively affect the WSI. Generally, the decrease in WSI of extrudates with increasing chick pea level (Figure 4) might indicate that the cumulative effect of the oil and protein from the chick pea had more effect than the dextrinzed starch.

Extrudates produced at 12% feed moisture had significantly higher WSI than those produced at 14% feed moisture ($p<0.05$). Similarly, higher WSI was reported at lower feed moisture for teff (Kebede *et al.,* 2010) and wheat based extrudates (Ding *et al*., 2006). As can be seen from figure 4, WSI showed an irregular type of trend with increasing chick pea level may be because of the interaction of chick pea level and feed moisture content that was statistically significant ($p<0.05$). The maximum mean WSI was observed for extrudates produced with 10% chick pea level at 14% feed moisture while the minimum mean value was observed for extrudates produced with 20% chick pea level at 12% feed moisture. This might be partly because as the chick pea proportion increased, the oil content increased and hence the oil may act as a barrier for moisture transfer to the starch, which results in lower WSI. Increase in WSI with decrease in feed moisture may be attributed to higher degradation of starch (Anderson *et al*., 1969) which produces more soluble lower chain starch aggregates. This could also be explained by the correlation of WSI which was positive against expansion ratio ($r = 0.45$, $p<0.05$) and negative against bulk density ($r = -0.58$).

Crispness

The mean sensory crispness scores as affected by chick pea level and feed moisture are given in Figure 5. Chick pea level had significant effect on crispness of extrudates ($p<0.05$) while the effect of feed moisture was not statistically significant. Higher chick pea level resulted in extrudates that had lower crispiness score. Cheng *et al.* (2007) also reported increased level of whey protein isolate resulted in reduced crispiness score while extruding corn starch - whey protein isolate blend. In this study, the decrease in crispness with higher chick pea level could be due to reduced expansion as explained above. Crispness was positively correlated with expansion ($r = 0.66$, $p<0.05$) and WSI ($r = 0.59$, $p<0.05$) and negatively correlated with bulk density ($r = -0.69$) indicating that the more accepted product was characterized by higher expansion, higher solubility and lower density. The crispness of expanded extrudate is a perception of the human being and is associated with the expansion and cell structure of the product (Ding *et al*., 2006). Although all the products had mean crispness values above the average, implying that they were liked by the judges, extrudates produced with 10% chick pea level at 14% feed moisture was rated maximum.

Conclusion

Chick pea level and feed moisture content were found to affect physical properties of extrudates. Chick pea level had dominant and significant effect on most of the physical properties of the extrudates.

Generally, higher chick pea level resulted in lower diametric expansion ratio, higher bulk density and higher WSI. The effect of feed moisture was not significant for all the quality parameters considered except WSI probably because narrow range of feed moisture content (12-14% wb) was used. It is important worth mentioning here that low moisture extrusion was adequate to produce puffed product from teff and chick pea blend.

Sensory evaluation for crispness revealed that all the products were rated above the average. The most accepted extrudate had a mean crispness score of 3.93 (on 5-point rating scale) and was produced with 10% chick pea level at 14% feed moisture. This product had a mean value of 1.58, 127.5 kg m^{-3}, 5.7 g g^{-1} and 30.92% for diametric expansion ratio, bulk density, WAI and WSI, respectively. Therefore, twin screw extrusion of teff and chick pea blend produces acceptable snack. Inclusion of different food additives could produce more acceptable product. Further study is recommended for antinutritional components.

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References

Anderson, R. A., Conway, H. F., Pfeifer, V. R. and Griffin, L. 1969. Gelatinization of corn grits by roll and extrusion cooking. Cereal Science Toddy 14: 4-12.

AOAC, 2005. Association of Official Analytical Chemists, 16th edition, Washington, DC.

Bultosa, G. 2007. Physicochemical characterstics of grain and flour in 13 teff [*Eragrostis teff (zucc.) Trotter*] grain varieties. Applied Sciences Research 3(12): 2042-2051.

CSA (Centeral Statistics Authority) 2012. Agricultural sample survey 2011/2012 Vol. I. report on area and production for major crops (private peasant holdings, meher season). Statistical Bulletin, May 2012, Ababa, Ethiopia.

Cheng, E. M., Alavi, S., Pearson, T. and Agbisit, R. 2007. Mechanical–acoustic and sensory evaluations of corn starch-whey protein isolate extrudates. Journal of Texture Studies 38: 473-498.

Chakraborty, P. and Banerjee, 2009. Otimization of extrusion process for production of expanded product from green gram and rice by response surface methodology. Journal of Scientific and Industrial Research 68:140-148.

Chinnaswamy, R. and Hanna, W.A. 1988. Relationship between amylose content and extrusion–expansion properties of corn starch. Cereal Chemistry 65(2): 138-143.

Deshpande, H. W. and Poshadri, A. 2011. Physical and sensory characteristics of extruded snacks prepared from Foxtail millet based composite flours. International Food Research Journal 18: 751-756.

De Mesa, N. J. E, Alavi, S., Singh, N., Shi, Y. C., Dogan, H. and Sang, Y., 2009. Soy rotein-fortified expanded extrudates: baseline study using normal corn starch. Journal of Food Engineering 90: 262-270.

Ding, Q. B., Ainsworth, P., Plonkell, A., Tucker, G. and Marson, H. 2006. The effect of extrusion conditions on the functional and physical properties of wheat based expanded snacks. Journal of Food Engineering 73: 142-148.

Golob, P., Farrel, G. and J. E. 2002. Orchard, (eds.).Crop post harvest science and technology, principles and practices. Volume I. Black well science ltd, Black well.

Ilo, S., Schoenlechner, R. and Berghofe, E. 2000. Role of lipids in the extrusion cooking processes, Grasasy Aceites (Austria) 51: 97-110.

Jukanti, A. K., Gaur, P. M. Gowda, C. L. L. and Chibbar, R. N. 2012. Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): a review. British Journal of Nutrition 108: S11-S26.

Kebede, L., Worku, S. Bultosa, G. and Yetnebere, S. 2010. Effect of extrusion operating conditions on the physical and sensory properties of teff *(Eragrostis teff* [Zucc.] Trotter) flour extrudates. Ethiopian Journal of Applied Science and Technology 1(1): 27-38.

Liu, K., and Hsieh, F. H. 2008. Protein-protein interactions during high-moisture extrusion for fibrous meat analogues and comparison of protein solubility methods using different solvent systems. Journal of Agricultural and Food Chemistry 56:2681-2687.

Mason, W. R., and Hosney, R. C. 1986. Factors affecting the viscosity of extrusion cooked wheat starch. Cereal Chemistry 63: 436-441.

Moraru, C.I. and J.L. Kokini, 2003. Nucleation and expansion during extrusion and microwave heating of cereal foods. Comprehensive Reviews in Food Science and Food Safety 2: 120-138.

Nwabueze, I. U. 2006. Water/oil absorption and solubility indices of extruded African breadfruit *(Treculia Africana)* blends. Journal of Food Technology 4(1): 64-69.

Pelembe, L. A. M., Erasmus, C. and Taylor, J. R. N. 2002. Development of a protein-rich composite sorghum-cowpea instant porridge by extrusion cooking process. Lebensm.- Wiss. u.-Technology 35: 120–127.

Sadik, J. A., Demelash, B. and Gizaw, M. 2013. Hydration kinetics of teff grain. Agric Eng Int: CIGR Journal 15(1): 124-130.

Singh, B., Sekhon, K. S. and Singh, N. 2007. Effect of moisture, temperature and level of pea grits on extrusion behavior and product characteristics of rice. Food Chemistry 100:198- 202.

Forsido S. F., F. F. and Ramaswamy, H. S. 2011. Protein rich extruded products from teff, corn and soy protein isolate blends. Ethiopian Journal of Applied Science and Technology 2(2): 75-90.

SPSS, 2007. Statistical package for social scientists. Prentice Hall Chicago, IL.

Piccinin, D. M. 2002. More about Ethiopian Food: Teff, Department of nutrition and food service. From an interview with Tsegazeab Woldetatios, Ph.D, agriculture contract interpreter at Harbor view medical center, Christine Wilson editor (4).

Suksomboon, A., Limroongreungrat, K. Sangnark, A. Thititumjariya, K. and Noomhorm, A. 2011. Effect of extrusion conditions on the physicochemical properties of a snack made from purple rice (Hom Nil) and soybean flour blend. International Journal of Food Science and Technology 46: 201-208.