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Full Length Research Paper

Processing quality of improved potato (*Solanum tuberosum L.*) cultivars as influenced by growing environment and blanching

Elfnesh, F.*, Tekalign T. and Solomon, W.

Department of Food Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia.

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A study was conducted to investigate the influence of growing environment and blanching on chips quality of five improved potato cultivars (Chiro, Zemen, Bedassa, Gabissa and Harchassa). The cultivars were grown at Langaie, Kulubi and Haramaya, all in the eastern part of Ethiopia. The highest tuber dry matter content (27.33%) and specific gravity (1.110 gcm^{-3}) were produced by cultivar Harchassa while the lowest dry matter content (20.33%) and specific gravity (1.078 gcm^{-3}) were by cultivar Zemen both grown at Haramaya condition. All the cultivars at all locations produced tubers with a dry matter content greater than 20.0% and a specific gravity of 1.070 gcm^{-3} which are within the acceptable range for chip processing. The tuber pH value ranged from 6.18 to 6.37 for the cultivars regardless of the growing environment. Location did not significantly affect tuber reducing sugar content and the cultivars produced tubers with low reducing sugar content that ranged from 0.036 to 0.051 g 100 g^{-1} fresh weight (FW). For chips making, peeled potatoes were sliced to 2.0 mm thickness, washed and surface-dried. In the blanching treatment, sliced potatoes were blanched at 90°C for about 5 min. Both blanched and unblanched slices were fried at 175°C for about 5 min using vegetable oil. The interaction effect of genotype and growing environment significantly influenced texture, bitterness, sweetness, crispiness and overall acceptability of potato chips. Blanching improved chips color, texture, sweetness, and crispness while reducing sourness and bitterness, ultimately increased the overall acceptability. In all cases, blanching resulted in a better acceptability of potato chips. The study indicated that the tested cultivars can be potentially be used for chips making. However, a comprehensive study under wide frying and blanching condition would be necessary to optimize the best operating conditions. The potato breeders should give emphasis for genotype × environment interaction while developing varieties suitable for processing.

Key words: Acceptability, chips, dry matter, G × E, reducing sugar, specific gravity.

INTRODUCTION

The quality of potato chip has been reported to be influenced by pre harvest factors mainly the growing condition and also influenced by variety (Salunkhe et al., 1989), inherent characteristics of potatoes like dry matter and specific gravity (Smith, 1968). Every factor that is part of the environment has the potential to cause differential performance that is associated with genotype environment interaction in potatoes (Feher, 1987).

The development of potato varieties with improved horticultural characteristics and a wide adaptability is important to all segments of potato industry. Processors and other users of potatoes would benefit from a more uniform product if varieties produce the same specific gravity when grown in differing environments (Johanson et al., 1967). According to Kabira and Berga (2003), some varieties are not suitable for the production of processed products due to low dry matter content. It is important for researchers to recommend to growers to use only those varieties that make good quality products both at harvest and after storage for various periods of time.

The production of lighter color chips acceptable to the market often requires some pretreatment of the sliced

*Corresponding author. E-mail: bubunafkot@yahoo.com Tel: 00251-255530364. Fax: 00251-255530325.

potatoes in the processing plants (Krokida et al., 2002). Prior to drying most food products are usually subjected to one form of pretreatments, among which blanching is one of the most important techniques (Leeratanarak et al., 2006). Blanching refers to the process of immersion of raw vegetables in a heated fluid (water, oil or acid) for a period of time. Blanching has a leaching effect on the sugars and serves to even out variations of sugar concentrations at or near the surfaces of the French fry strips. This gives a lighter and more uniform color on frying. It is also used to extract the reducing sugars and asparagines from the surface of potatoes in order to reduce browning, particularly the formation of brown spots (Grob et al., 2003). Blanching reduced glucose and asparagines content by average 76 and 68%, respectively in potatoes according to Pedreschi et al. (2004).

In Ethiopia, the majority of ware potatoes produced is used for preparation of different kinds of traditional foods. Although, there are some food processing industries in the country, none of them are involved in the processing of potatoes. Moreover, consumption of potato chips is not common in the country except in the big hotels and restaurants. Recently, however, small scale potato chips processors are flourishing in cities and big towns. About eleven improved potato cultivars have been developed by Haramaya University and widely used for commercial purpose. In developing these varieties, much emphasis was given to productivity per unit area and late blight reaction while less emphasis was given to processing quality. To meet the demand of the processing industry, it is essential to evaluate the fitness of the released cultivars for processing and to incorporate processing quality as a yardstick in variety development procedure. Hence, this study was initiated to study the effect of growing environment and blanching on chips processing quality of five improved potato cultivars.

MATERIALS AND METHODS

Site description

During the main cropping season of 2007, three similar field experiments were conducted at Haramaya University main campus, Langaie and Kulubi; all located in the eastern part of Ethiopia. The latitude, longitude, altitude, soil type, mean annual rainfall, and temperature of the experimental sites are indicated in Table 1.

Experimental materials and design

Five regionally released potato varieties, namely Chiro, Zemen, Bedassa, Gabissa and Harchassa were used for the study. At each location, while planting the varieties were arranged in a Randomized Complete Block Design and replicated three times. The land was prepared and well-sprouted tubers of each cultivar were planted in five rows of ten hills each at spacing of 75 and 30 cm between rows and plants, respectively. Plots within a replication were arranged continuously and end plots were bordered by two rows of potato plants. Spacing between plots and replication were 1 and 1.5 m, respectively. At each site, plots were fertilized with 150 kg phosphorus ha^{-1} in the form of diammonium phosphate and 100 kg nitrogen ha^{-1} in the form of urea. The entire rate of phosphorus and the half rate of the nitrogen fertilizer were applied at the time of planting. The remaining half of the nitrogen was applied at flowering. Appropriate crop management practices like cultivation, weeding and earthing up were carried out according to the regional recommendation (Teriessa, 1997). Two week before harvesting the haulm was removed using sickle and tubers were hand dug using fork.

Data collection

Tuber specific gravity was measured using the weight in air and weight in water method (Gould, 1995). To determine dry tuber matter content tubers, ten tubers were taken at random from the harvested plot, washed, chopped and mixed. Two sub-samples 200 g each were taken and pre-dried at a temperature of 60°C for 15 h and further dried for 3 h at 105°C in a drying oven. Dry matter content was calculated as the ratio between dry and fresh mass and expressed as a percentage. To determine tuber pH, five potato tubers were peeled and homogenized in a juice extractor (Model 31 JE 35 New Hartford Connecticut 06057 USA). The pH was then directly measured using HI 9025 microcomputer pH meter and the test was preformed in three replications according to Pardo et al. (2000).

The juice prepared for pH determination was used for reducing sugars analysis. Ten milliliters of the juice were added to 15 ml of 80% ethanol, mixed and heated in boiling water bath for 40 min. After extraction, 1 ml saturated Pb $(CH_3\ COO)_2\ 3H_2O$ and 1 ml Na_2HPO_4 were added and the content was mixed by gentle shaking and filtered. The filtered extract was made up to 50 ml with distilled water. An aliquot was diluted to 25 ml with 1 ml copper reagent in a test tube and heated for 20 minutes in a boiling water bath. The heated contents were cooled under running tap water without shaking. Arsenomolybdate color reagent (1 ml) was added to the cooled content made up to 10 ml with distilled water and left for about 10 minutes to allow color development, after which the absorbance was determined by a spectrophotometer (Jenway, model 6100) at 540 nm. The reducing sugar was calculated using the formulae developed by Somogyi et al. (1952).

Blanching treatment

Blanching of potato tuber slices was done according to Lisinka et al. (2007). Healthy and undamaged tubers which are of uniform size were selected, washed, peeled and sliced to a thickness of about 2 mm using Mandalian slicer. The sliced samples were washed in water and dried using cloth towel. The dried slices were blanched at 90°C for about 5 min using shaking constant temperature water bath (Weston-s-make Avon). The blanched slices were dried before frying to remove free water. The experiments were carried out in three replications.

Frying processes

In frying potato slices, procedures described by Lisinka et al. (2007) were employed. Before frying, the frying oil (OKI liquid vegetable oil) was heated for about 10 to 15 min until the required temperature of 175°C reached and it was measured using thermometer. For each blanched and unblanched treatments 700 g slices were fried using a fryer (Beckers, 24047 Italy) until the bubbling ceases (3 to 4 min) and all experiments were carried out in three replications.

Table 1. Description of the experimental sites.

Site	Latitude	Longitude	Altitude (m)	Soil type	Mean annual	
					Rainfall (mm)	Temperature (°C)
Haramaya	09°26' N	043°03'E	1980	Alluvial soil	780	23.4/8.5
Kulubi	09°26' N	041°42'E	2330	Vertisol	862	19.5/7.3
Langaie	09°26'N	041°46'E	2025	Vertisol	810	22.5/9.4

Quality evaluation of potato chips

Texture and color measurement

The texture of potato chips was determined according to Moreno-Perez et al. (1996). The texture of potato chips was evaluated using hardness taster (Kiya Seisakusho. Ltd. Tokyo, Japan). The chips were placed on a hollow planar base and force was applied to the samples until the samples were broken. Chips color was measured using a standard color chart having scale ranging from grade 1 to 5 (1 = the lightest color (white to cream), 2 = light tan, 3 = dark tan, 4 = brown and 5 = dark brown, (Munsell Color Company, USDA 1988) chip color between grade 1 and 3 is commercially acceptable (Amoros et al., 2000).

Sensory evaluation

The sensory test was conducted in Food Science and Postharvest Technology laboratory, Haramaya University, following the procedure of Watts et al. (1989). A ten-member, untrained but experienced panelists consisting of students, and faculty staff of the University were selected to rate the quality attributes. A five point test was used to measure taste (sourness, bitterness and sweetness) and crispness (Kita, 2002) whereas 9-point hedonic test was employed to assess the flavor and overall acceptability according to Yost et al. (2006). Coded samples (samples of one location at once) were served for each panelist separately in similar plastic trays at 10 a.m. in the morning. Water was provided to the panelists to rinse their mouth before and between testing samples as suggested by Watts et al. (1989) and the evaluation was repeated 3 times for each sample.

Data analysis

Analysis of variance (ANOVA) was carried out using MSTAT-C statistical software packages (MSTAT-C, 1991). Means were compared using least significant differences (LSD). Correlations between parameters were made when appropriate.

As suggested by Watts et al. (1989), in analyzing the sensory data, the 5 point scale and the 9 point hedonic scales were used and the numerical values for each sample were tabulated and analyzed by ANOVA to determine whether significance differences in mean degree of scoring points exist among the samples or not.

RESULTS, DISCUSSION AND CONCLUSION

Tuber dry matter content and specific gravity

Dry matter content and specific gravity of tubers were significantly influenced by the interaction effect of growing environment and cultivars (Table 2). Tubers of cultivar Harchassa grown at Haramaya gave the highest dry matter content (27.33%) and specific gravity (1.110 gcm^{-3}). On the contrary, Zemen grown at the same site produced tubers with lower dry matter content (20.33%) and specific gravity (1.078 gcm^{-3}). High specific gravity is an indication that the raw potatoes will produce high chip volume due to high dry matter content. Fitzpatrick et al. (1964) categorized tuber specific gravity values as low (less than 1.077), intermediate (between 1.077 and 1.086, and high (more than 1.086). Accordingly, tubers of Harchassa grown at Haramaya failed under high specific gravity group while tubers harvested from the other two locations failed in the intermediate group indicating that they are fit for processing.

Kabira and Berga (2003) reported that potatoes with a dry matter content of 20 to 24% are ideal for making French fries while those with a dry matter content of up to 24% are ideal for preparing crisps. They also pointed that potato tubers should have a specific gravity value of more than 1.080 and tubers with specific gravity value less than 1.070 are generally unacceptable for processing. In this study, all cultivars had dry matter content above 20% and a specific gravity higher than 1.070 regardless of the growing condition, indicating that they are suitable for chip making.

Generally, in the present study, high specific gravity and dry matter value were obtained from late matured cultivars like Harchassa followed by Gabissa. Dry matter of the tuber was positively and strongly (r = 0. 80**) correlated with day to physiological maturity indicating that delaying maturity has substantially contributed for tuber dry matter increment. Iwama et al. (1975) reported that increasing the growing period of potato increased the dry mass of the leaves, stems and roots. This is in agreement with the findings of Burton (1966) who reported that the dry matter content of early maturing cultivars is usually lower than that of the later maturing varieties. Variation in tuber dry matter content may be attributed to cultivars inherent difference in the production of total solids. Burton (1966) reported that genetic differences among varieties play a role in their ability to produce high solids when grown on the same test plot. Dry matter content is subjected to the influence of both the environment and genotypes (Miller et al., 1975; Tai and Coleman, 1999). Dry matter content was positively and high significantly correlated with specific gravity (r = 0.99**) indicating that specific gravity is a true indicator of the

Table 2. The interactions effect of location and cultivars on tuber dry matter content and specific gravity of potato.

Location	Cultivar	Dry matter (%)	Specific gravity (gcm^{-3})
	Chiro	21.67^{de}	1.084^{e}
	Zemen	21.83^{de}	1.085^{e}
	Bedassa	21.83^{de}	1.085^{e}
Langaie	Gabissa	22.00^{cde}	1.086^{e}
	Harchassa	24.00^{bcd}	1.095^{cd}
	Chiro	20.67^{e}	1.080^{fg}
	Zemen	20.97^{e}	1.081^{f}
	Bedassa	22.00^{cde}	1.086^{e}
	Gabissa	25.67^{ab}	1.103^{b}
Kulubi	Harchassa	21.97^{cde}	1.086^{e}
	Chiro	20.50^{e}	1.079^{fg}
	Zemen	20.33^{e}	1.078^{g}
	Bedassa	23.67^{bcd}	1.094^{d}
Haramaya	Gabissa	24.33^{bc}	1.097^{c}
	Harchassa	27.33^{a}	1.110^{a}
F-test		**	**
CV (%)		4.83	0.46

** = significant at P=1%. Means followed by the same letter within a column are not significantly different at P=1%.

Table 3. The effect of location and cultivar on tuber pH and reducing sugar content and chips color, sourness and flavor.

Treatment	pH	Reducing sugar ($g100\ g^{-1}$ FW)	Color	Sourness	Flavor
Location					
Langaie	6.26^{a}	0.037^{a}	1.47^{ab}	1.62^{a}	7.36^{a}
Kulubi	6.31^{a}	0.049^{a}	1.60^{a}	1.54^{a}	7.41^{a}
Haramaya	6.32^{a}	0.038^{a}	1.17^{b}	1.52^{a}	7.33^{a}
F-test	ns	ns	**	ns	ns
Cultivar					
Chiro	6.37^{a}	0.051^{a}	1.28^{ab}	1.59^{a}	7.36^{bc}
Zemen	6.28^{a}	0.045^{a}	1.61^{a}	1.64^{a}	7.12^{c}
Bedassa	6.35^{a}	0.038^{a}	1.61^{a}	1.57^{a}	7.18^{c}
Gabissa	6.18^{b}	0.036^{a}	1.39^{ab}	1.48^{a}	7.67^{a}
Harchassa	6.28^{a}	0.036^{a}	1.17^{b}	1.52^{a}	7.51^{ab}
F-test	**	ns	**	ns	**
CV (%)	1.24	18.14	16.88	14.08	4.52

ns and ** = non significant and significant at P=5% and P= 1%, respectively. Means followed by the same letter within a column are not significantly different at P= 1%.

amount of dry matter (total solid) of tubers which is concurring with the report of Tekalign and Hammes (2005).

pH and reducing sugar

There was a highly significant difference in pH among cultivars during harvesting but the growing environment and the cultivar × environment interaction did not significantly influence pH (Table 3). Regardless of the cultivar, tubers harvested from Langaie, Kulubi and Haramaya gave a pH value of 6.26, 6.31, and 6.32, respectively. For all cultivars, the pH value was between 6.18 and 6.37. This finding is in agreement with the findings of Nourian et al. (2002) who reported that pH of raw potatoes to be usually around 6.0. This relatively higher pH value may be because of lower level of reducing sugar which causes the juice to become weak acid.

Cultivars, growing environment and their interaction did not significantly affect the tuber reducing sugar content (Table 3). Regardless of the cultivar, tubers harvested from Langaie, Kulubi and Haramaya exhibited a reducing sugar content of 0.037, 0.049 and 0.038 g 100 g^{-1} of FW, respectively. The maximum reducing sugar content was obtained for cultivar Chiro (0.051 g 100 g^{-1} FW) and the minimum for cultivars Gabissa and Harchassa (0.036 g 100 g^{-1} FW). Generally, low reducing sugar content was obtained from all cultivars that may be due to the reduced rate of respiration at the time of harvesting. Hyde and Morison (1964) investigated that the reducing sugars and phosphorylase activities at harvest for all varieties were low, whereas the pH levels were relatively high and chip color was good at this stage. Stevenson et al. (1964) showed that light colored chips can be made from varieties directly harvested from field and large differences are found between them in their reactions to various storage treatments. The presence of low reducing sugar content makes the cultivars suitable for chips processing. This is in agreement with the findings of Moreira et al. (1999) who reported that low reducing sugar content (below 0.25% and preferably below 0.10%) is desired for the production of potato chips.

Sensory attributes

Color

Growing environment as well as cultivar significantly influenced potato chips color while their interaction did not (Table 3). The color of all cultivars ranges between 1 and 2 where 1 is light color and 2 is light tan which is commercially acceptable. This may be due to their lower reducing sugar content (below 0.051 g 100 g^{-1} FW) whichis suitable to produce commercially acceptable chip color. In the same way, regardless of the cultivar, the color range for the three locations lies between 1(light color) to 2 (light tan) indicating that the color is within the acceptable range. In this study, the observed low reducing sugar content and relatively higher pH value of potato probably makes the cultivars lighter and light tan in chips color which is commercially acceptable.

Color in processed products such as potato chips can be affected by several factors including product composition and processing conditions (Rodriguez-Saona and Wrolstad, 1997) and influences consumer acceptability (Fennema, 1996). For instance, common browning of foods during heating occurs when reducing sugars and a free amino acid or amino group react in the Maillard reaction (Fennema, 1996). Marquez and Anon (1986) studied color development during potato frying and found that both reducing sugars and amino acids are involved in the color development of fried potatoes, reducing sugars being the limiting factor. Moreira et al. (1999) reported that low reducing sugar content (below 0.25% and preferably below 0.1%) is desired for the production of potato chips. The key reducing sugars in potatoes that are responsible for melanoidin pigment formation are glucose and fructose (Kumar et al., 2004).

Blanching treatment significantly influence the color of the chips (Table 5). Blanched chips produce almost lighter (1.2) color while the unblanched chip color resembles to light tan (1.6). This could be attributed to the effect of the blanching treatment on the reducing sugar content. In order to reduce the reducing sugars before frying, tubers are usually blanched to leach out soluble sugars (Brown and Morales, 1970). According to Kabira and Berga (2003) hot water blanching at 65-100°C before frying destroy enzyme activity and leaches out, reducing sugars and other chemical constituents that cause off color and off flavor. Blanching treatments are used to reduce browning of fried products by leaching out Maillard reactions which play a predominant role in color and acrylamide formation during frying (Pedreschi et al., 2004). Blanching lead to lighter in color potato chips than those of the control after frying at 150°C (Pedreschi et al., 2005). Blanching prior to frying improves the color and texture of potato chips and could reduce in some cases the oil up take (Califano and Calvelo, 1978). Rodriguez-Saona and Wrolstad (1997) found that reducing sugars had the biggest influence on lightness, producing the brighter colors when they were absent; however, reducing sugars did not entirely predict color quality when present at low concentrations.

Texture

The interaction effect of growing environment and cultivars significantly influenced the texture of potato chips (Table 4). The maximum force (10.20 N) to break the chips was required for cultivar Chiro which was grown under Langaie condition while the minimum (6.57 N) was needed for chips made from Gabissa grown at Kulubi condition. This could be attributed to the influence of tuber dry matter content on the texture of the chips as measured by the force required to break them. In general, chips prepared from tubers with higher dry matter have weak structure compared with those prepared from tubers that have lower dry matter. This was confirmed with the significant negative correlation between texture and dry matter content (r = - 0.53*) and specific gravity (r = - 0.54*). Moyano et al. (2007) showed that the texture of potato chips was found to be directly related to specific gravity, total solids, starch content, cell size, and surface area and pectin. Crisps obtained from potatoes rich in dry matter (above 25%) can exhibit hard textures, where as crisps made of tubers with low dry matter content are characterized by greasy and sticky textures (Kataz and

Table 4. The interaction effect of location and cultivars on chips texture, bitterness, sweetness, crispiness and overall acceptability.

Location	Cultivar	Texture(N)	Bitterness	Sweetness	Crispiness	Over all acceptability
	Chiro	10.20^{a}	1.28^{d}	3.00^{g}	3.67^{cd}	7.27^{ef}
	Zemen	8.37^{a-f}	1.52^{bcd}	2.84g^{hi}	3.80^{a-d}	7.33^{def}
	Bedassa	7.19^{def}	1.45^{bcd}	2.70^{i}	4.08^{a-d}	7.30^{ef}
Langaie	Gabissa	7.65^{b-f}	1.45^{bcd}	3.23^{cd}	3.55^{de}	7.55^{b-e}
	Harchassa	7.44^{c-f}	1.33^{cd}	3.17^{de}	3.92^{a-d}	7.85^{a-d}
	Chiro	8.18^{b-f}	1.32^{d}	3.12^{ef}	3.78^{bcd}	7.25^{ef}
	Zemen	7.33^{def}	1.48^{bcd}	3.02^{g}	4.13^{abc}	7.30^{ef}
	Bedassa	8.63^{a-e}	1.43^{bcd}	3.15^{def}	4.37^{a}	7.27^{ef}
	Gabissa	6.56^{f}	1.30^{d}	3.34^{bc}	4.33^{ab}	8.10^{a}
Kulubi	Harchassa	8.12^{b-f}	1.57^{bc}	3.17^{de}	4.05^{a-d}	7.53^{b-e}
	Chiro	9.47^{ab}	1.83^{a}	3.12^{ef}	2.98^{ef}	6.85^{fg}
	Zemen	9.42^{abc}	1.62^{ab}	2.95^{gh}	2.58^{f}	6.67^{g}
	Bedassa	8.83^{a-d}	1.65^{ab}	3.13^{ef}	3.53^{de}	7.48^{cde}
Haramaya	Gabissa	8.32^{a-f}	1.57^{bc}	3.43^{ab}	3.95^{a-d}	7.98^{abc}
	Harchassa	6.67^{ef}	1.45^{bcd}	3.45^{a}	4.17^{abc}	8.07^{ab}
F-test		**	**	**	**	**
CV %)		15.99	14.48	9.19	9.76	14.68

** = significant at P=1%. Means followed by the same letter within a column are not significantly different at P=1%.

Table 5. The effect of blanching on sensory attributes of flavor, overall acceptability, texture and color of potato chips.

Treatment	Color	Texture (N)	Sourness	Bitterness	Sweetness	Crispiness	Flavor	Over all acceptability
Unblanched	1.62^{a}	10.42^{a}	1.68^{a}	1.61^{a}	2.93^{b}	3.42^{b}	7.18^{b}	7.28^{b}
Blanched	1.20^{b}	5.89^{b}	1.44^{b}	1.36^{b}	3.30^{a}	4.17^{a}	7.57^{a}	7.72^{a}
Significance level	**	**	**	**	**	**	**	**
CV (%)	16.88	15.99	14.08	14.48	13.04	11.41	4.52	6.68

** = significant at P=1%.Means followed by the same letter within a column are not significantly different at P=1%.

(Kataz and Lacuna, 1981). Texture in food products has dominant contribution to the overall quality and acceptability (Kayacier and Singh, 2003). Crisp texture is connected with the dry matter content of raw potato tubers (Lisinska and Leszynski, 1989).

The data in Table 5 showed a significant influence of blanching on chips texture. Blanched chips needed remarkably less force (5.89 N) to break than the unblanched group (10.42 N). This is due to the fact that blanching improved the texture of the chips and made them less hardy

Blanching treatment significantly influenced the sourness of the chips (Table 5). The mean sourness rates for chips made after being blanched and unblanched were 1.44 and 1.68, respectively. Blanching reduced the sourness of the chips which could be due its leaching effect of reducing sugar and other chemicals which may be responsible to induce sourness in chips. According to Kabira and Berga (2003) hot water blanching at 65-100°C before frying destroy enzyme activity and leaches out, reducing sugars and other chemical constituents that cause off color and off flavor.

Bitterness

The interaction of cultivars and growing environment significantly influenced bitterness of potato chips as presented in Table 4. The maximum and minimum bitterness rate was found to be 1.83 and 1.28 for Chiro cultivar grown at Haramaya and Langaie, respectively (1= not bitter and 2 = less bitter). This result indicates the difference in the quality of chips made from tubers grown in different environment. The reduced bitterness of the chips could be due to the minimal glykoalkaloids level of tubers at harvest. Asmamaw et al. (2010) showed that the loss in taste of chips prepared from tubers stored for extended period may due to the increase in the concentration of glykoalkaloids level of tubers.

Bitterness of potato chips was significantly influenced by blanching (Table 5). In all cases blanched samples get better score by the panels. The blanched and unblanched tubers resulted in chips having bitterness rate of 1.36 and 1.61, respectively (1= not bitter and 2 = less bitter). This result showed that blanching leached out some (crispier). According to Leeratanarak et al. (2006) blanching and drying temperature significantly affected the hardiness of potato chips under certain conditions while the drying method did not show any significant influence on the hardiness. They pointed out that blanching caused starch gelatinization and softening of structure leading to less hardness of dried starchy products. They also reported that unblanched chips had the maximum hardness in all of the cases. Pimpaporn et al. (2007) found that blanching reduces the hardness and shrinkage of the product. While blanching at low temperatures (55 to 75°C) lead to a firm texture (Bartolome and Hoff, 1972), blanching at high temperatures (80 to 100°C) for alternatively long period of times (15 min) leads to loss of firmness (Andersson et al., 1994).

Sourness

The growing environment, cultivars and their interaction did not significantly influence the sourness of the chips (Table 3). Potato chips prepared from tubers harvested from Langaie, Kulubi and Haramaya rates 1.62, 1.54 and 1.52, respectively, with respect to sourness. The sourness rates for all cultivars lie between 1.48 to 1.64 where 1= not sour and 2 = less sour. chemical responsible for bitter test in addition to reducing sugar.

Sweetness

The interaction effect of location and cultivar significantly influenced the sweetness of potato chips (Table 4). The maximum rate for sweetness was found to be 3.45 for chips made from Harchassa cultivar grown at Haramaya whereas the minimum was 2.70 from Bedassa cultivars grown at Langaie (1=not sweet and 5 = very sweet).

In general, blanching appeared to result sweeter (3.30) chips as compared to ones made from unblanched potato slices (2.93) as presented in Table 5. Blanching is an essential step before processing of any vegetable as it destroys the enzymes and microorganisms and help in prevention of quality deterioration particularly during drying, freezing, frying or storage. Besides, it also expels the air entrapped intercellularly inside the tissues (Lee, 1958). As the potatoes are highly sensitive to enzymatic activities, adequate blanching becomes essential before processing or preservation (Talburt and Smith, 1975).

Flavor

The growing environment did not significantly influence the flavor of potato chips while the tested cultivars showed variation regarding chips flavor (Table 3). The highest flavor score was given for Gabissa (7.67) and Harchassa (7.51) while the minimum was for cultivar Zemen (7.12) and Bedassa (7.18), and Chiro being intermediate. According to the panelists, the flavor score of all of the cultivars lies between 7 and 8 indicating that the flavor of the cultivars are between liked moderately to liked very much.

In the study, flavor of the chips was positively and significantly correlated with dry matter content (r = 0.72**) and specific gravity (r = 0.73**) of the tubers. This implies that potato with high dry matter content and specific gravity are required to produce chips with acceptable flavor. In addition, flavor is one of the important quality factors of potato chips and is affected mainly by the type of oil used to fry chips, flavor compounds inherent in the raw potatoes, and added flavorings (Smith, 1987).

Blanched treatment significantly influenced the chips flavor as indicated in Table 5. Chips made from blanched slices secured the highest score (7.57) while the least (7.18) was for the unblanched group. Blanching involves a short and quick heat treatment preferably in a wet medium either by steam or hot water which provides uniform heating and high heat transfer rate (Lee, 1958). Hot water blanching is by far the most popular and commercially adopted process as it is the simplest and most economical technique although prolonged hot water blanching results in considerable loss of nutrients such as carbohydrates, proteins, water soluble minerals, vitamins and sugars (Lee, 1958). Hot water blanching at a temperature between 65 and 100°C before frying reported to destroy enzyme activity and leaches out, reducing sugars and other chemical constituents that cause off flavor in chips (Kabira and Berga, 2003).

Crispiness

The interaction of cultivars and growing environment significantly influenced the crispiness of potato chips (Table 4). Bedassa grown at Kulubi produced crispy chips (4.37) while Zemen grown at Haramaya produced moderately crispy (2.58) chips according to 1 to 5 scale (1 = not crispy and 5 = very crispy). This is strongly linked to the difference in tuber dry matter content of the cultivars since Gabissa grown at Kulubi showed the highest tuber dry matter content (25.67%) while Zemen grown at Haramaya the least (20.33%). The result indicated that the dry matter content of cultivars influences the crispiness of the chips. Lisinska and Leszynski (1989) has established that crispy texture is associated with the dry matter content of raw potato tubers, chips obtained from potatoes rich in dry matter (above 25%) can exhibit hard textures, whereas crispiness of chips made from potatoes with low dry matter are characterized by greasy and sticky textures. Kita (2002) also reported that percentage of dry matter in potatoes for crisp production should be 20-25% and that of starch should be more than 15%. Crispiness was positively and significantly associated with dry matter content (r = 0.54*) and specific gravity (r = 0.54*) indicating that tubers with high dry matter content and specific gravity produce crispy potato chips.

Blanching treatment significantly affected the crispness of the chips (Table 5). The maximum crispiness (4.17) was given for chips prepared from blanched slices while the least (2.93) was for unblanched one indicting that blanching improves the crispiness of potato chips. For potato chips, a very crispy texture is expected since it is an indicator of freshness and high quality (Moreira et al., 1999). The crispy structure of potato chips is the result of changes at the cellular and sub-cellular levels in the outermost layers of the product. Blanching causes a permanent modification of the cellular structure in the potato tissue (Hughes et al., 1975; Andersson et al., 1994). The heat treatment during blanching affects the typical potato cell by altering the cytoplasmic membrane. Heat destroys the differential permeability of the membrane letting water to enter the cells and intercellular spaces there by expelling gases and other volatiles, causing also loss of water soluble nutrients (sugars, vitamins, and minerals) to the blanch water (Andersson et al., 1994). During pre-treatment, changes occur in the cell membranes, which play a key role in the changes that occur within the tissue during further processing (Taiwo et al., 2001).

Overall acceptability

The overall acceptability of potato chips was significantly influenced by the interaction of cultivars and growing environment (Table 4). The highest acceptability scores were given for Gabissa (8.10) and Harchassa (8.07) grown at Kulubi and Haramaya, respectively which corresponds to like very much whereas the least scores were for Zemen (6.67) and Chiro (6.85) both grown at Haramaya which is close to like moderately. Similar to the crispiness, the acceptances of the potato chips were related with tuber dry matter content and specific gravity in such a way that tubers with high value gave chips with higher over all acceptance than tubers with less dry matter content and specific gravity. This association was further supported by the observed strong correlation between overall acceptability and tuber dry matter content (r = 0. 92**) and specific gravity (r = 0.93**). Hence, tubers with high dry matter content and specific gravity are essential for quality chips processing.

The over all acceptability of chips was significantly influenced by blanching as presented in Table 5. A better score of 7.7 (liked very much) and 7.3 (liked moderately) were given for blanched and unblanched chips, respectively. It is speculated that blanching increases crispiness, flavor, color, sweetness and reduces sourness and bitterness of the chips through leaching out the reducing sugars and other chemicals which affects the quality of the chips thereby improves the overall acceptance. Andersson et al. (1994) reported that in the case of potato processing, blanching is used to inactivate peroxides, to improve the texture, color and, to some extent, the flavor of final product. Potato blanching helps in activate enzymes that lead to some quality degradations (Moreno-Perez et al., 1996).

Genotype by growing environment interaction has significantly influenced tuber dry matter content, specific gravity, chip texture, bitterness, sweetness, crispiness, and over all acceptability suggesting that genotype × environment interaction must be taken into consideration in variety development meant for processing. The study indicated that the five of the tested cultivars could potentially be used for chips making. Blanching in hot water (at 90°C) for about 5 min has significantly improved the over all qualities of chips hence tuber slices must be blanching prior to frying to prepare quality chips.

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