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PROCESSING QUALITY OF SELECTED POTATO (*SOLANUM TUBEROSUM* L.) CULTIVARS GROWN IN RWANDA

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ABSTRACT: The aim of this study was to investigate processing quality of ten potato cultivars grown in Rwanda and their potential utilization in food products. Potatoes were grown in Busogo farm in 2016/17. Specific gravity (SG), dry matter (DM), starch and sugars were analyzed. There was a significant difference in all studied parameters at ($P < 0.05$). Specific gravity ranged from 1.075 for Kigega to 1.099 for Kinigi. Dry matter ranged from 20.45% for CIP392617.54 to 25.93% for Kirundo. Starch content was 14.33% for CIP392617.54 to 19.28% for Kirundo on Fresh Weight Basis (FWB). There was a significant positive correlation among SG, DM and starch. Reducing sugars were 0.10% for Kirundo and Sangema to 0.20% for Mabondo, non-reducing sugars ranged from 0.16% for Kirundo to 0.35% for Mabondo and total sugars from 0.26% for Kirundo to 0.55% for Mabondo on FWB. Most of tested varieties/clones have high DM and low reducing sugars and are suitable for processing into fried and dehydrated products. Kigega and CIP392617.54 are more suitable for boiling.

KEYWORDS: Dry matter, potato cultivars, specific gravity, sugars, starch

INTRODUCTION

Potato (*Solanum tuberosum L.*) is a crop of solanaceae family. It is considered as an excellent vegetable due to its high starch content comparing to other vegetables. It is originated from South America in Peru near the lake Titicaca from there it spread all over the world. It grows in all continents except Antarctica (Burke, 2016). It is grown in more than 160 countries in the world and it is consumed by more than one billion of people (Donnelly and Kubow, 2011). It is fourth in total production and contributor to human calories after maize, wheat, and rice (Burke, 2016). It is a food of people from different socio-economic classes.

Potato is among the main crops grown and consumed in Rwanda. It is among priority crops and it ranks the second to supply calorie after cassava (Haverkort *et al.*, 2015). It is grown all over the country, but northwest of the country accounts for 90% of the total production (USAID, 2010). Potatoes are consumed fresh mainly through boiling. However, due to increase in population in urban areas, mode of potato consumption is changing. Nowadays, there is increase in demand of processed potato products and the main ones are French fries and potato crisps. Other types of potato processed products are also likely to emerge in the near future with increase in urbanization and changing lifestyle. Processing industries require potatoes with specific characteristics which allow them to produce products of high quality with high consumers' preference. The most promising factors determining potato

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processing quality are specific gravity, dry matter, starch and sugars content.

Specific gravity is a quick indicator of potato quality. Potato specific gravity varies from one variety to another. Specific gravity is related to the yield of processed potato products. Increase of 0.005 in specific gravity is related to the increase by 1% of yield in chips (Vreugdenhil *et al.*, 2007). To get good quality fried product, SG of potatoes should be between 1.0701 to 1.0850 (Feltran *et al.*, 2004). Similarly, roasting, baking and dehydrated products require potatoes with high specific gravity, whereas for boiling and canning low specific gravity potatoes can be used (Ekin, 2011). Specific gravity of potato should be taken into consideration while choosing potato for specific use.

Dry matter is an important factor in potato processing as it contributes to the quality and yield of processed products. Dry matter of potatoes was reported to range from 13 to 37% with the average of 24% (Lister and Munro, 2000). Starch content contributes up to 75% of the dry matter (Lister and Munro, 2000; Bandana *et al.*, 2016). Dry matter increases with increase in starch content. Potatoes with high dry matter are preferred for dehydrated products, stock feed and fried products (Lister and Munro, 2000). Potatoes suitable for French fries should have dry matter of 20 to 24%, while for crisps it should be up to 24% (Kabira and Lemaga, 2003). High dry matter increases yield and reduces oil absorption during processing (Burke, 2016). Variability in dry matter affects uniformity of processed products and quality.

The concentration of sugars varies from one potato variety to another and environmental conditions plays an important role in sugar accumulation. The total sugar varies from 0.05 to 8% with average of 0.5%, while reducing sugars vary from 0.0 to 0.5% with average of 0.3% on fresh weight basis and above 2% of total sugar on dry basis (Lister and Munro, 2000). Potatoes with high amount of reducing sugars are not suitable for processing of dehydrated and fried potato products (Lister and Munro, 2000). The amount of reducing sugars is related to factors like genotype, environmental conditions, cultural practices, postharvest factors and storage conditions (Kabira and Lemaga, 2003). Potentially good processing cultivars have sucrose of 1.91 mg/g and potentially poor have 4.53 mg/g (Kumar *et al.*, 2004). Storage at low temperature activates invertase enzyme which hydrolyzes sucrose into glucose and fructose in the process called "cold induced sweetening" and the ideal storage temperature for potatoes is 8-12°C at relative humidity of 85 to 90%, senescence sweetening occurs during prolonged storage at elevated temperatures (Kumar *et al.*, 2004). High amount of reducing sugar is unacceptable as it leads to the formation of acrylamide which is a by product of Maillard reaction and is considered as potential carcinogen (Zhu *et al.*, 2010). It is associated to bitter taste and unfavourable brown color of the products.

There is increase of potato production and new varieties are being developed due to advancement of potato breeding in Rwanda. There is also change in mode of potato consumption due to urbanization and change in life style. However, potatoes in Rwanda have not been studied for their processing potential. Therefore, the objective of this study is to investigate processing quality of potato cultivars grown in Rwanda and their potential application in food products.

MATERIALS AND METHODS

Potatoes were grown in Busogo farm of the University of Rwanda located in Musanze District, Northern Province of Rwanda. It is geographically located at 1°33′26′′ S and 29°32′39′′E. The site is characterized by Andosol due to volcanic soil. The average temperature is 16.2°C with average annual rainfall of 1420 mm (Climate-Data.Org, 2016). The experiment was laid out in Randomized Complete Block Design (RCBD) in three replications and ten treatments representing cultivars known as factors in this experiment. Six varieties *viz*. Gikungu, Kigega, Kinigi, Kirundo, Mabondo, and Sangema and four clones *viz*. CIP399075.22, CIP392617.54, CIP 393251.64 and CIP399062.115 were used in the study. Experimental unit of 3.2 × 1.8 m^2 was used. Adjacent plots were separated by guard rows of 0.8 m and spacing was 80 cm between the rows and 30 cm within the rows. They were grown under standard cultural conditions in the year of 2016/17. Fertilization rate was 300 kg of compound fertilizer 17-17-17 per hectare.

Sample preparation

Healthy potatoes of processing size of 40 mm diameter and above were selected for biochemical analysis. About one kilogram of fresh potatoes was selected randomly from the central rows of each plot and three plots were used for each cultivar (three replications). They were washed in portable water, grated into small pieces and sundried for one day. They were then ground into powder, kept in clean dry containers and refrigerated (4±2)°C for further analysis. Potato powder was thoroughly mixed and used for biochemical analysis and the results were converted in fresh weight basis using the method used by Reiling (2011).

Specific gravity and dry matter: The method suggested by CIP (2006) was used for specific gravity and dry matter. For specific gravity potatoes were washed, dried and 5 kg were weighed using portable electronic digital handheld scale (Lcd, FA113FA0E7Q95NAFAMZ) in the air and in the tap water. Specific gravity was calculated as follows:

$$\text{Spefific gravity} = \frac{\text{Weight in air}}{\text{Weight in air-weight in water}} \quad \text{.................................(1)}$$

For determination of dry matter, nine potatoes of processing size were sliced and thoroughly mixed and 10 g were weighed in a crucible with three replications and heated in forced air oven at 80°C for 72 h. The dry matter was calculated using the formula below:

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100 \quad \text{.................................(2)}$$

For determination of starch content, reducing sugars and total sugars: Methods described by Lane and Eynon was used (AOAC, 2000).

Non-reducing sugars was computed as the difference between total sugars and reducing sugars.

Statistical analysis: Data were subjected to analysis of variance (ANOVA) and means separated by the Turkey's test at 5% level of significance using Statistical Analysis System (SAS version 9.2) with General Linear Model Procedure (Proc GLM). Orthogonal contrast was performed on varieties vs clones(SAS institute Inc., 2008). Strength of association between variables was analyzed using Pearson's correlation coefficient.

RESULTS AND DISCUSSION

Specific gravity of potato cultivars

Specific gravity is an important parameter for selection of potatoes for specific use. Potato varieties/clones tested in this study were statistically significantly different at ($P<0.05$). The specific gravity ranged from 1.075 to 1.099. Specific gravity of Kinigi was the highest, while of Kigega and CIP392617.54 were the lowest. Orthogonal contrast showed a significant difference between cultivars and clones at ($P<0.05$). On average, cultivars had higher specific gravity than clones. These results are in agreement with the ones reported by Mohammed (2016) where specific gravity of seventeen varieties grown in three different locations of mid and low altitude and two cropping seasons ranged from 1.061 to 1.095. Similarly, Soboka *et al*. (2017) reported the specific gravity in range of 1.086 to 1.107 in six potato varieties grown in two different locations. The results were higher than Ekin (2011) who reported specific gravity of 1.065 to 1.077 in eight potato varieties. Specific gravity was reported to be influenced by genetic and environmental factors (Mohammed, 2016; Soboka *et al*., 2017). Fitzpatrick *et al*. (1964) classified specific gravity of potatoes in three categories where specific gravity above 1.086 is classified as high, between 1.077 and 1.086 as intermediate and below 1.077 as low. Based on this classification, Kigega and CIP392617.54 fall in low specific gravity range, Kinigi, Kirundo, Mabondo, CIP393251.64, CIP399062.115 and Sangema had high specific gravity, while CIP399075.22 and Gikungue exhibited intermediate specific gravity as depicted in **Table 1.** Potatoes with high specific gravity are suitable for baking, frying, mashing and chipping; while low specific gravity are for boiling and canning (Ekin, 2011). All potato varieties/clones tested in this study qualified for frying as SG in potatoes for frying should range from 1.0701 to 1.0850 (Feltran *et al*., 2004). Potatoes for dehydrated products, French fries and chips, should have 1.080 and above specific gravity and for canning it should be less than 1.070 (Marwaha *et al*., 2010). In this regard, Kigega and CIP392617.54 are the only potato cultivars which were not qualified for crisps, French fries and dehydrated products. Moreover, it was reported that increase of each 0.005 in specific gravity corresponds to the increase in yield of fried products by 1% (Vreugdenhil *et al*., 2007).Specific gravity is an indicator of potato quality and it is related to dry matter.

Dry matter content

The dry matter of potatoes is the most important factor used to determine the processing quality of potatoes. This study revealed positive correlation between dry matter and specific gravity (r = 0.902). The correlation between specific gravity and dry matter was also reported by Mohammed (2016). Dry matter of studied sample was statistically significant at ($P<0.05$). It ranged from 20.45% for CIP392617.54 to 25.93% for Kirundo as shown in the **Table 1**. Orthogonal contrast showed a significant difference between dry matter of cultivars and clones at ($P < 0.05$). On average varieties had more dry matter than clones. These results align with the study of Elfnesh *et al*. (2011)where dry matter ranged from 20.33 to 27.33% in five varieties from three distinct areas. Similarly, Soboka *et al.* (2017) reported dry matter ranging from 19.41 to 26.61% in six varieties grown in two different locations. Ekin (2011) revealed that potatoes with dry matter above 22% are suitable for crisps and French fries. Similarly, Kabira and Lemaga (2003) reported that potatoes with dry matter of 20 to 24% are suitable for French fries, while those up to 24% are ideal for crisps. Furthermore, potatoes for dehydrated products, French fries and crisps should have 20% and above dry matter, while the ones for canning should have less than 18% of dry matter (Marwaha *et al*., 2010). It was further reported that the lower limit is 19.5% for French fries and 20% for crisps and upper limit is 25% for French fries (Vreugdenhil *et al*., 2007). Potatoes with high dry matter are related to less oil absorption, high yield, less energy consumption and crispy texture, but high dry matter is not preferred for canned potatoes due to sloughing (Marwaha *et al*., 2010). Potatoes in this study have acceptable dry matter for dehydrated and fried products.

Starch content

Starch occupies the highest portion of dry matter and potatoes with high starch content have high dry matter. Potato starch in this study ranged from 14.33% for CIP392617.54 to 19.28% FWB for Kirundo and the difference was statistically significant at (*P < 0.05*) as presented in the **Table 1.** Orthogonal contrast showed a significant difference between varieties and clones at (*P < 0.05*). On average, varieties had higher starch content than clones. Starch content of potato on fresh weight was reported to range from 10 to 30% (Donnelly and Kubow, 2011). Furthermore, Soboka *et al.* (2017) reported starch content ranging from 14.61 to 19.19% in six varieties grown in two different locations. High starch content is favourable and it is associated with high yield and texture of the products due to high gelatinization during processing (Bandana *et al.*, 2016). Starch content is categorized as highest if it is above 19% and is considered better for mashing, between 16 to 19% as high and better for roasting, and between 13 to 15.9% as intermediate and is better for cooking or roasting and low if less than 12% and is used for boiling (Ekin, 2011). Based on this classification, potatoes in this study fall in high and intermediate categories and are suitable for roasting and cooking. Moreover, potato with starch content of 15% and above are suitable for starch production, 16-20% for chips,15-18% for French fries and 15-19% for dehydrated products (Lisiěska *et al.*, 2009). In this regard, Kinigi, Kirundo, Mabondo and CIP399062.115 are suitable for chips, dehydrated potatoes and starch production. There was a significant positive correlation (r = 0.976) between starch and specific gravity and between starch and dry matter (r = 0.963).Correlation of specific gravity, dry matter and starch was also reported by Mohammed (2016). Potato tubers in this study are suitable for dehydrated products, frying, roasting and boiling. The quality and yield of the products may increase with the increase of starch content.

Table 1. Specific gravity, starch and dry matter of fresh potato tubers.

	Cultivars	Specific Gravity	Starch %	Dry matter %
Varieties	Gikungu	1.080±0.003^{cd}	15.23±0.33^{de}	20.94±0.69^{cd}
	Kigega	1.075±0.001^{d}	14.72±0.22^{e}	21.12±0.38^{cd}
	Kinigi	1.099±0.001^{a}	18.18±0.18^{ab}	23.88±0.10^{b}
	Kirundo	1.097±0.002^{ab}	19.28±0.11^{a}	25.93±0.11^{a}
	Mabondo	1.088±0.001^{bc}	17.01±0.19^{bc}	23.67±0.09^{b}
	Sangema	1.086±0.004^{c}	16.38±0.35^{bc}	22.93±0.68^{b}
Clones	CIP399075.22	1.085±0.002^{cd}	16.34±0.15^{cd}	22.53±0.06^{bc}
	CIP392617.54	1.075±0.001^{d}	14.33±0.24^{e}	20.45±0.48^{d}
	CIP393251.64	1.088±0.003^{abc}	16.49±0.16^{cd}	23.33±0.25^{b}
	CIP399062.115	1.088±0.001^{abc}	16.87±0.21^{bc}	22.51±0.41^{bc}
	Minimum	1.075	14.33	20.45
	Maximum	1.099	19.28	25.93
	CV	0.33	3.23	2.70
	MSD	0.0103	1.5592	1.7951

MSD: Minimum significant difference at 5% Tukey; Means followed by the same letter in the column do not differ by Tukey's test at 5%.

Reducing sugars, non-reducing sugars and total sugars

Sugars are important for determination of the quality of potato products and are classified as reducing and non-reducing sugars. There was a statistically significant difference in sugars among the studied cultivars at (*P<0.05*). Reducing sugars ranged from 0.10% for Kirundo and Sangema to 0.20% for Mabondo, non-reducing sugars from 0.16% for Kirundo to 0.35% for Mabondo and total sugars from 0.26% for Kirundo to 0.55%FWB for Mabondo (**Table 2)**. Orthogonal contrast showed a significant difference between cultivars and clones in sugar content at (*P < 0.05*).The results align with the earlier reports (Bhattacharjee *et al.*, 2014) where four varieties exhibited reducing sugars in range of 0.23 to 0.32% which are higher than those reported in the present study, non-reducing sugars in range of 0.19 to 0.32% and total sugars in range of 0.45 to 0.61%. On the other hand, Elfnesh *et al*. (2011) reported low reducing sugars ranging from 0.036 to 0.051g/100g FWB for five varieties from three distinct areas. Fried products require low sugar content to prevent browning of the final product. The sugar content of potatoes is related to the genotype and numerous pre- and postharvest factors. The main pre-harvest factors affecting sugar content include crop maturity, temperature during growth, mineral nutrition and irrigation, while vital post- harvest factors comprise mechanical stresses and storage Conditions. Each genotype necessitates an ideal pre- and post-harvest treatment to keep low sugar levels and any kind of stress results in sugar accumulations (Kumar *et al.*, 2004).

It was suggested that reducing sugars should be 0.25% for dehydrated products, 0.15% for French fries, less than 0.1% for crisps and 0.5% for canned potatoes (Marwaha *et al.*, 2010). Varieties in this study, particularly Kirundo and Sangema were low in reducing sugars and can be considered as good for processing. During frying, reducing sugars react with free amino acids and results in Maillard reaction. The color of fried products is related to the reducing sugars and is light in product prepared from low reducing sugars containing potatoes and dark in potatoes with high reducing sugars. Dark fried products are not preferred by consumers. The preferred color for fried products is golden which is associated with relatively low content of reducing sugars.

CONCLUSIONS

The tubers specific gravity, dry matter, starch content and sugars were analyzed. Specific gravity of potato is a quick indicator of potato dry matter. All potatoes in this study showed high and medium specific gravity except Kigega and CIP392617.54. High and medium specific gravities are indicators of potato suitability for development of dehydrated products, mashing, frying and roasting, while low specific gravity is an indicator of potatoes for boiling, salad and canning. Specific gravity correlated positively with dry matter and starch content. In the present study samples contained dry matter above 20%. All the studied potato varieties/ clones have low reducing sugars except for Mabondo. Low sugar content is an indicator of good processing quality especially for frying and dehydration. This study provides useful information for potential technological use of potatoes for consumers, processing industries and to the scientific community.

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Table 2. Sugar content of potato in percentage of fresh weight.

	Cultivars	Reducing sugars	Non-reducing sugars	Total Sugars
Varieties	Gikungu	0.12±0.01[cde]	0.19±0.00[de]	0.31±0.01[de]
	Kigega	0.13±0.02[bcd]	0.22±0.00[bcd]	0.35±0.02[bcd]
	Kinigi	0.14±0.01[bc]	0.23±0.02[bc]	0.37±0.03[bc]
	Kirundo	0.10±0.01[e]	0.16±0.01[e]	0.26±0.02[e]
	Mabondo	0.20±0.01[a]	0.35±0.02[a]	0.55±0.04[a]
	Sangema	0.10±0.00[de]	0.21±0.01[cd]	0.31±0.01[de]
Clones	CIP399075.22	0.12±0.00[bcde]	0.20±0.00[cde]	0.32±0.01[cd]
	CIP392617.54	0.14±0.01[bc]	0.24±0.01[bc]	0.38±0.02[b]
	CIP393251.64	0.15±0.02[b]	0.25±0.01[b]	0.40±0.02[b]
	CIP399062.115	0.13±0.01[bc]	0.23±0.01[bcd]	0.36±0.02[bcd]
	Minimum	0.10	0.16	0.26
	Maximum	0.20	0.35	0.55
	CV	7.67	6.43	5.12
	MSD	0.0299	0.0432	0.0544

MSD: Minimum significant difference by Tukey 5%; Means followed by the same letter in the column do not differ by Tukey's test at 5%.

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