RESEARCH PROGRAM ON Roots, Tubers and Bananas

CGIAR

Technical report:
Effect of Storage Conditions on the Processing Quality of Different Potato Varieties Grown in Eastern Uganda

Expanding Utilization of Roots, Tubers and Bananas and Reducing Their Postharvest Losses

RTB ENDURE

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The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a broad alliance led by the International Potato Center (CIP) jointly with Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute for Tropical Agriculture (IITA), and CIRAD in collaboration with research and development partners. Our shared purpose is to tap the underutilized potential of root, tuber and banana crops for improving nutrition and food security, increasing incomes and fostering greater gender equity, especially among the world's poorest and most vulnerable populations.

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SUMMARY

In 2016, trials were conducted over two seasons to evaluate varieties already registered in Uganda and clones from the International Potato Center's breeding program for suitability for postharvest storage. These varieties were studied for their storage behavior, physical and chemical properties with special reference to their potential in chip processing and consumer acceptability in ambient stores made of rice straw for insulation, cement plaster on the walls with ventilation. The stores were located in Kapchorwa Town council (1,800 masl), Bennet (2,300 masl), and Mbale Town Council (1,200 masl). Varieties and clones with short dormancy are not suitable for storage, with Shangi, having the shortest dormancy periods. All other clones have dormancy periods of 2 months or greater, making them suitable to store provided they meet variety-specific requirements for specific outlets. The highest dry matter content was recorded in 398208.704 and 393385.4, averaging of 21.9 and 20.8%, respectively, making them appropriate for processing, while the lowest dry matter content was recorded in Rwanshaka and Victoria, averaging 19.2 and 18.5% respectively, making them more suitable for table use. Clone 392797.22 was the most overall acceptable, followed by Rwangume, Kinigi, Rwanshaka. Clone 393385.39 had the lowest consumer acceptability score overall followed by 393079.4. Therefore all clones tested in this trial are suitable for storage with the exception of clones 393385.39, 393079.4 and Shangi.

1.0 INTRODUCTION

The favorable environment in Eastern Uganda enables growing of *Solanum* potato, however the limited access to improved varieties and appropriate storage facilities lead to physical and economic losses. In order to address these challenges, new potato varieties and ambient storage structures were introduced. This study was hence carried out to investigate the effectiveness of the ambient stores in maintaining potato quality and the storability of the newly introduced varieties.

Eleven potato varieties including 392797.22, 398208.704, 393079.4, and 393385.39, Kingi, Victoria, Rwangume, Rwanshaka, Cruza, Bumbamagara and Shangi were stored in ambient stores in Kapchorwa Town council (1,800 m), Bennet (2,300 m), and Mbale Town Council (1,200 m). These varieties were studied for their storage behavior, physical and chemical properties with special reference to their potential in chip processing and consumer acceptability. Farmers potatoes/associations potatoes were also stored in traditional stores.

General objective

The general objective of the study was to evaluate the effectiveness of the improved storage structures in maintaining quality of different potato varieties.

Specific objectives

1. To determine the effect of storage conditions on the physicochemical and sprouting properties of the potatoes
2. To evaluate the effect of storage conditions on processing quality of potatoes
3. To determine the sensory qualities and consumer acceptability of potatoes stored under different conditions.

2.0 FIELD ACTIVITIES

Tuber storage in ambient stores

Potato varieties were stored in four ambient stores located at different altitudes as shown in Table 1 below. The ambient store in Bennet was located at the highest altitude while that in Mbale town was located at the lowest altitude.

Table1: Altitudes of the different ambient stores

Store	Altitude
Bennet	2,300 m
Kapchorwa	1,800 m
Mbale	1,200 m
Wanale	2,000 m

Season 1 tuber storage

Potato tubers were stored in four ambient stores at the sites of Bennet, Mbale, Kapchorwa and Wanale. The potato tubers were stored from October to December 2015. The stored potato varieties did not make a complete set hence the study design was incomplete.

Season 2 tuber storage
Potato tubers were stored in three ambient stores at the sites of Bennet, Kapchorwa and Mbale from June to September 2016. No potatoes were stored in Wanale store due to the partial collapse of the ambient store that needed to be repaired. The stored potato varieties did not make a complete set hence the study design was also incomplete. During season II storage, the ambient store in Mbale also showed structural problems to be addressed before completion of the experiment making data sets incomplete. Storage of potatoes in the Wanale store was later done in season III after maintenance of the store.

Tuber storage in traditional stores
No farmer potatoes were stored in the traditional stores during season I and II. Storage of the farmer potatoes was delayed but done later with season III.

Sampling and evaluation
This was done every after 3 weeks of storage. Tubers were weighed in stores to ascertain the weight lost; they were also checked to determine the number of rotten and sprouted tubers. Tubers were randomly sampled from the various ambient stores and taken for laboratory assessment.

Laboratory assessment
Biochemical assessment was carried out on fresh potato samples in the food chemistry laboratory to determine moisture content, dry matter content, pH, titratable acidity, reducing sugars and total sugars. The samples were also processed into chips and the potato chips were assessed in the laboratory to determine their chip color, chip oil uptake, chip texture and chip moisture content. The chips were also presented to the panelists for sensory evaluation to rate their color, texture, flavor and rate of oiliness.

Data analysis
Data was analyzed through analysis of variance (ANOVA) using SPSS Statistical software version 19 and means compared using LSD (Least Significant Difference). Pearson correlation analysis was used to determine relationships between chip fry color and level of reducing sugars, pH levels and reducing sugars, chip texture and dry matter content. In order to balance up the design, some varieties which were not making a complete set were dropped to make a better analysis of results.

3.0 SEASON ONE

3.1 INTRODUCTION

The first storage season contained eleven potato varieties namely 392797.22, 398208.704, 393079.4, 393385.39, Cruza, Kingi, Victoria, Shangi, Bumbamagara, Rwangume and Rwanshaki which were studied for their storage behavior, physical and chemical properties, with special reference to their potential in chip processing and consumer acceptability.

The tubers were stored in four ambient stores located at Bennet, Kapchorwa, Wanale and Mbale. The store in Bennet contained all the eleven varieties while the store in Kapchorwa contained 392797.22, 393079.4, Kinigi, Rwangume, Rwanshaki and Victoria. The store in Mbale contained 392797.22, Bumbamagara and Rwangume. The store in Wanale contained 392797.22 and Rwangume.

For quality testing six (6) tubers per clone and per replication were randomly picked from each ambient store on day one and every after 3 weeks of storage. Evaluations were done for nine weeks out of the predicted fifteen weeks from October 2015 to December 2015.

3.2 PHYSIO-CHEMICAL PROPERTIES

Weight loss

The weight loss results are indicated in Table 2. There was gradual tuber weight loss with storage time. The highest levels of weight loss were recorded in Rwanshaki at 11.92% and 14.73% in the 6th and 9th week, respectively. Lowest level of weight loss was recorded in 398208.704 at 1.8% and 4.55%.

The gradual increase in weight loss is due to respiration which converts the valuable starch in the presence of oxygen to carbon dioxide, water and heat (Mohammad, 2010 & Tester et al., 2005). Weight loss is primarily attributed to the water loss that occurs through the outer most skin tissues during the processes of respiration. The gradual loss in weight is also likely to be due to transpiration with water loss through the tuber skin pores with the help of evaporation (Mathur and Singh, 2008).

Variations in weight loss among varieties can be attributed to the skin surface content. Bumbamagara and Rwanshaki lost more weight compared to 398208.704 as they have a fairly smooth light skin while 398208.704 is tough skinned. This in agreement with the findings of Kabira and Lemaga (2003) who reported that weight loss can be attributed to the nature of the skin surface. The findings are similar to those of Ezekiel et al. (2004) and Pande et al. (2007) who reported that weight loss in unsprouted tubers occurs through the periderm, and to a minimum proportion through the lenticels.

Varieties with a thick periderm (a large number of cell layers in the periderm) and less lenticels on the tuber surface are therefore likely to lose less weight compared to those with a thin periderm.

In the last weeks of storage, weight loss is likely to have been due to sprouting in the tubers. Sprouting leads to release of visible buds and shoots which are very vulnerable to transpiration therefore releasing more water from the tubers (Pande et al., 2007).

Table 2: Change in percentage weight loss of the varieties with storage time

Variety	Percentage (%) Weight Loss		
	Storage time		
	week 3	week 6	week 9
392797.22	0	3.68 ± 1.75	5.49 ± 1.9
393079.4	0	2.36 ± 1.5	5.99 ± 3.6
393385.39	0	3.95 ± 0.5	7.89 ± 1.1
398208.704	0	1.80 ± 0.78	4.55 ± 1.5
Bumbamagara	0	10.24 ± 1.8	-
Cruza	0	8.62 ± 0.8	-
Kinigi	0	4.74 ± 2.9	8.71 ± 3.5
Rwangume	0	4.78 ± 2.2	-
Rwanshaki	0	11.92 ± 5.7	14.73 ± 6.2
Victoria	0	3.49 ± 1.94	6.96 ± 3.8

- Experiment discontinued due to too much sprouting and tuber rotting

Disease and rotting

During storage incidences of disease were noticed in 392797.22 only with black heart disease dominating and no cases of tuber decay were observed.

The low storage temperatures in the ambient stores are likely to have minimized incidences of disease and rotting as reported by Kibar (2012).

Dormancy and sprouting behavior

The sprouting behavior results are indicated in Table 3. There was an increase in the rate of sprouting with storage time. Shangi, Cruza and Bumbamagara had sprouted tubers at 0 weeks of storage. Shangi, Bumbamagara and Cruza had the shortest dormancy periods. By the end of the 9th week of storage, Shangi, Cruza, Bumbamagara and Rwangume had 100% of their tubers sprouted.

In general 393385.39, 392797.22, 398208.704 and 393079.4 had a longer dormancy period with variety 393385.39 having 10% tubers sprouted by the 9th week of storage hence having the longest dormancy period followed by 398208.704 with 67.7% of the tubers sprouted by the 9th week of storage.

The difference in the rate of sprouting among the varieties throughout the storage time is likely to be due to the difference in genetic makeup of each variety (Frazier et al., 2004).

Table 3: Change in percentage sprouting with storage time

Variety	Percentage (%) sprouting			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	NS	8.0 ± 3.5	45.0 ± 1.5	81.0 ± 0.5
393079.4	NS	8.0 ± 4.9	27.0 ± 0.5	77.0 ± 0.5
393385.39	NS	NS	NS	10.0 ± 0.6
398208.704	NS	8.0 ± 1.9	19.0 ± 0.0	68.0 ± 2.5
Bumbamagara	35.0 ± 12	78.0 ± 14.0	100.0 ± 0.0	-
Cruza	31.0 ± 3.8	83.0 ± 5.7	100.0 ± 0.0	-
Kinigi	1.0 ± 1.4	15.0 ± 6.6	59.0 ± 6.8	83.0 ± 10.0
Rwangume	NS	55.0 ± 8.6	94.0 ± 7.8	100.0 ± 0.0
Rwanshaki	NS	4.0 ± 10.6	4.0 ± 8.7	4.0 ± 3.7
Shangi	81.0 ± 7.7	100.0 ± 0.0	-	-
Victoria	NS	41.0 ± 1.7	79.0 ± 9.6	1. 92.0 ± 7.2

-Experiment discontinued due to too much sprouting and tuber rotting.
NS: Not sprouted

Moisture Content and dry matter content

The moisture content and dry matter content results are indicated in Table 4 and 5, respectively.

Moisture content

There was a gradual loss of moisture in the varieties within the first three weeks of storage and an increase in moisture content between week 6 and week 9. The highest moisture content was recorded in Cruza at 80.25%, Rwanshaki at 80.53% and 398208.704 at 80.34%. The lowest moisture content was recorded in Shangi at 67.06% and Bumbamagara at 65.77%.

The loss of moisture can be attributed to the water lost during transpiration and evaporation while the increase in moisture content is a result of water liberated as a product of respiration.

Table 4: Variation in moisture content of the varieties with storage time

Variety		Percentage (%) moisture loss		
		Storage time		
	Week 0	Week 3	Week 6	Week 9
392797.22	76.22 ± 1.19	75.09 ± 1.84	77.93 ± 1.15	79.83 ± 0.19
393079.4	76.82 ± 0.33	75.91 ± 0.45	77.99 ± 0.98	78.35 ± 0.84
393385.39	77.48 ± 0.00	76.43 ± 0.26	77.99 ± 0.04	78.96 ± 0.16
398208.704	78.06 ± 0.06	77.49 ± 0.05	79.36 ± 1.47	80.34 ± 0.31
Bumbamagara	65.77 ± 4.40	-	-	-
Cruza	79.31 ± 0.25	80.28 ± 1.00	-	-
Kinigi	77.09 ± 2.87	76.23 ± 3.7	77.99 ± 2.37	79.81 ± 0.32
Rwangume	76.88 ± 1.58	78.26 ± 0.67	79.66 ±0.48	-
Rwanshaki	78.70 ± 0.12	77.77 ± 0.12	79.61 ± 0.07	80.53 ± 0.09
Shangi	67.06 ± 0.00	-	-	-
Victoria	77.19 ± 0.57	76.46 ± 0.85	77.93 ± 0.26	78.75 ± 0.07

- Experiment discontinued due to too much sprouting and tuber rotting

Dry matter content

There was a general increase in dry matter content in the first 3 weeks of storage and as the storage time progressed to 6 weeks there was a significant decrease in the dry matter content. The highest dry matter content was recorded in Bumbamagara at 36.25% and the lowest dry matter content was recorded in Rwanshaki at 19.47%.

The decrease in dry matter content with storage time corroborates the results of Freitas et al. (2012) and Addisu et al. (2014) who reported a significant decreasing trend in the specific gravity and dry matter content of the potato tubers stored for 180 days at 12° C.

The decrease in the potato tuber dry matter with storage time can be attributed to the gradual respiratory biochemical starch breakdown to sugars that is used up to maintain life of the tuber with concurrent production of carbon dioxide and water vapor (Bisognin et al., 2008 & Addisu et al., 2014). Most of the potatoes had a dry matter content between 20-24% indicating that they are ideal for processing into chips (Kabira and Lemaga, 2003).

Table 5: Variation in dry matter content with storage time

Variety	Percentage (%) dry matter content			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	23.37 ± 1.1	24.91 ± 1.4	22.06 ± 1.1	21.65 ± 0.4
393079.4	23.17 ± 0.6	24.09 ± 0.7	22.17 ± 1.0	21.65 ± 0.9
393385.39	22.52 ± 0.1	23.57 ± 0.5	22.01 ± 0.2	21.04 ± 0.4
398208.704	21.94 ± 0.3	22.50 ± 0.2	20.63 ± 1.2	19.65 ± 0.6
Bumbamagara	36.25 ± 3.0	-	-	-
Cruza	20.68 ± 0.5	19.72 ± 1.0	-	-
Kinigi	22.91 ± 1.7	23.77 ± 1.9	22.01 ± 1.5	20.19 ± 0.6
Rwangume	23.12 ± 1.3	21.73 ± 0.8	20.34 ± 0.7	-
Rwanshaki	21.29 ± 0.3	22.22 ± 0.4	20.38 ± 0.3	19.47 ± 0.3
Shangi	32.93 ± 1.1	-	-	-
Victoria	22.80 ± 0.8	23.53 ± 0.9	22.10 ± 0.5	21.25 ± 0.3

- Experiment discontinued due to too much sprouting and tuber rotting

Specific gravity

The specific gravity results are indicated in Table 6. There was an increasing trend in specific gravity between 0 and 3 weeks' time for all the varieties and there was a reduction in specific gravity with the later months of storage. Cruza had the lowest specific gravity at 1.079 while Bumbamagara and Shangi had the highest specific gravity at 1.163 and 1.138 respectively. The decrease in specific gravity with the last 3 weeks of storage is likely to be due to the decrease in dry matter content (Freitas et al., 2012).

Most of the potato had a higher specific gravity at the beginning of storage and were suitable for processing in the chips with little oil uptake and good texture according to Abong (2011). However there was a drop in specific gravity with storage time hence affecting the quality of the chips.

Table 6: Changes in Specific gravity with storage time

Variety	Specific gravity			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	1.093	1.100	1.087	1.077
393079.4	1.092	1.096	1.087	1.085
393385.39	1.089	1.094	1.086	1.082
398208.704	1.086	1.082	1.079	1.075
Bumbamagara	1.163	1.149	1.144	-
Cruza	1.08	1.078	-	-
Kinigi	1.091	1.095	1.086	1.078
Rwangume	1.092	1.085	1.079	-
Rwanshaki	1.083	1.087	1.079	1.074
Shangi	1.138	-	-	-
Victoria	1.092	1.094	1.087	1.083

-Experiment discontinued due to too much sprouting and tuber rotting

pH and titratable acidity

The pH and titratable acidity results are indicated in Table 7 and 8 respectively.

pH

The pH range of the tubers was found to be between 6.7 and 5.95 .The highest pH levels on average were in Shangi at 6.7 and the lowest were recorded in Rwanshaki ranging from 5.95 to 6.31. There was a general decrease in pH with in the first 3 weeks of storage time and an increase in pH between the 6^{th} and 9^{th} week of storage. This finding is in agreement with the findings of Nourian et al. (2002) who reported pH of raw potatoes to be usually around 6.0.

The relatively higher pH values at the beginning of the storage period may be because of lower level of reducing sugars which causes the juice to become weak acid. The fall in the pH levels as storage time progresses is likely to be due to the increase in the level of reducing sugars which leads to darkening of the chips (Nourian et al., 2002).

Table 7: Changes in pH with storage time

Variety		pH		
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	6.44 ± 0.03	6.39 ± 0.10	6.36 ± 0.05	6.47 ± 0.01
393079.4	6.30 ± 0.01	6.35 ± 0.15	6.31 ± 0.15	6.39 ± 0.11
393385.39	6.30 ± 0.05	6.11 ± 0.04	6.22 ± 0.01	6.32 ± 0.01
398208.704	6.16 ± 0.05	6.13 ± 0.01	6.24 ± 0.01	6.29 ± 0.01
Bumbamagara	6.61 ± 0.03	6.48 ± 0.30	6.40 ± 0.08	-
Cruza	6.40 ± 0.03	6.37 ± 0.02	-	-
Kinigi	6.19 ± 0.02	6.35 ± 0.02	6.27 ± 0.05	6.49 ± 0.10
Rwangume	6.38 ± 0.02	6.27 ± 0.08	6.38 ± 0.06	-
Rwanshaki	5.95 ± 0.13	6.31 ± 0.02	6.27 ± 0.02	6.29 ± 0.01
Shangi	6.70 ± 0.17	-	-	-
Victoria	6.22 ± 0.03	6.28 ± 0.02	6.29 ± 0.15	6.32 ± 0.07

-Experiment discontinued due to too much sprouting and tuber rotting

Titratable acidity

There was a general decrease in titratable acidity between week 0 and week 3 followed by a general increase in titratable acidity in week 9. The highest levels of titratable acidity were recorded in Rwanshaki at 0.01 to 0.08 while the lowest titratable acidity was recorded in 398208.704 at 0.01.

The various changes in titratable acidity are in agreement with the findings of Batu and Şen (2013) who reported that titratable acidity decreases at a certain time and then increases smoothly during storage regardless of harvest time.

The changes in titratable acidity are linked to be due to the many organic acids found in the potato tuber which include citric, malic, oxalic and fumaric acids which change with storage time (Batu and Şen, 2013). As the citric acid content decreases, the malic acid content increases. The changes in titratable acidity had a positive correlation with changes in pH.

Table 8: Changes in titratable acidity with storage time

Variety	Titratable acidity			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	0.03 ± 0.003	0.03 ± 0.035	0.01 ± 0.002	0.04 ± 0.050
393079.4	0.05 ±0.080	0.01 ±0.004	0.01 ± 0.002	0.02 ± 0.002
393385.39	0.02 ± 0.001	0.01 ± 0.007	0.01 ± 0.001	0.04 ± 0.001
398208.704	0.01± 0.002	0.02 ± 0.002	0.01 ± 0.002	0.02 ± 0.001
Bumbamagara	0.02 ± 0.001	0.01 ± 0.008	0.01 ± 0.007	-
Cruza	0.02 ± 0.004	0.02 ± 0.008	-	-
Kinigi	0.02 ± 0.002	0.02 ± 0.004	0.02 ± 0.005	0.02 ± 0.002
Rwangume	0.02 ± 0.004	0.02 ± 0.007	0.02 ± 0.005	-
Rwanshaki	0.01 ± 0.004	0.07 ± 0.070	0.08 ± 0.007	0.02 ± 0.010
Shangi	0.03 ± 0.003	-	-	-
Victoria	0.02 ± 0.002	0.02 ± 0.001	0.02 ± 0.005	0.02 ± 0.002

- Experiment discontinued due to too much sprouting and tuber rotting

Reducing sugars and total sugars
The results for reducing sugars and total sugars are indicated in Table 9 and 10 respectively.

Reducing sugars
There was a general increase in the reducing sugar content of the tubers between week 6 and week 9. Tubers exhibited a reducing sugar content ranging from 0.04 to 0.70%. The highest reducing sugar content was obtained for 398208.704 at 0.42% to 0.70% while the lowest reducing sugars were recorded in Rwanshaki at 0.04% to 0.32%.

There is an increase in reducing sugars content in potato tubers stored at low temperatures (Kumar, 2011). Some varieties stored at moderate temperatures accumulate reducing sugar (glucose and fructose) within two weeks of storage to cause dark colored chips while other varieties are capable of withstanding storage at low temperature (Watada, 1955 & Saran and Chhabra, 2014).

The difference in reducing sugar content across the varieties can also be attributed to growing season temperatures, soil moisture, tuber maturity at harvest and storage temperatures (Kumar, 2011 & Mareček et al., 2013).

The higher levels of reducing sugars at the end of the storage period is likely be due to high sprouting and dormancy break where sugars are released to cater for growth (Fauconnier et al., 2002). The increase in reducing sugar content among the varieties in the last weeks of storage contributed to the dark color in chips which affects their quality and consumer acceptability.

Table 9: Changes in reducing sugar content with storage time

Variety	Percentage % reducing sugars	
	Storage time	
	Week 6	Week 9
392797.22	0.26 ± 0.07	0.27 ± 0.06
393079.4	0.34 ± 0.04	0.32 ± 0.03
393385.39	0.22 ± 0.03	0.29 ± 0.03
398208.704	0.42 ± 0.02	0.70 ± 0.03
Bumbamagara	0.37 ± 0.20	-
Kinigi	0.30 ± 0.03	0.38 ± 0.05
Rwanshaki	0.04 ± 0.02	0.32 ± 0.10
Victoria	0.29 ± 0.03	0.25 ± 0.10

- Experiment discontinued due to too much sprouting and tuber rotting

Total sugars
There was also a noticeable increase in total sugars between week 6 and week 9. Tubers had total reducing sugars ranging from 0.21% to 0.76%. The highest level of total sugars was recorded in 392797.22 at 0.509% to 0.655% and 398208.704 at 0.415% to 0.76% while the lowest total sugars were recorded in Victoria at 0.21% to 0.22%.

Table 10: Changes in total sugar content with storage time

Variety	Percentage (%) total sugars	
	Storage time	
	Week 6	Week 9
392797.22	0.51 ± 0.09	0.66 ± 0.04
393079.4	0.41 ± 0.03	0.47 ± 0.03
393385.39	0.45 ± 0.04	0.64 ± 0.04
398208.704	0.42 ± 0.01	0.76 ± 0.01
Kinigi	0.41 ± 0.02	0.58 ± 0.18
Rwanshaki	0.34 ± 0.04	0.46 ± 0.04
Victoria	0.21 ± 0.23	0.22 ± 0.24

3.3 PROCESSING QUALITY

Potato processing quality was evaluated basing on chip color, chip texture, chip oil uptake and chip moisture content.

Chip texture

The results for changes in chip texture are indicated in Table 11. There was a general decrease in chip texture between week 6 and week 9. Rwangume and 393079.4 had the highest texture from the FT 327 penetrometer both having 1.59 kg while the lowest texture was in Rwanshaki with 1.06 kg.

The decrease in chip texture is due to the decrease in dry matter content of the raw potatoes of which starch is a major contributor (Kita, 2002 & Pedreschi et al., 2001). The decrease in texture is also attributed to the decrease in specific gravity of the varieties (Lefort et al., 2003).

Table 11: Changes in chip texture with storage time

Variety	Chip texture (kg)	
	Storage time	
	Week 6	Week 9
392797.22	1.52 ± 0.28	1.02 ± 0.19
393079.4	1.59 ± 0.37	1.13 ± 0.13
393385.39	1.27 ± 0.02	1.25 ± 0.06
398208.704	1.33 ± 0.14	1.25 ± 0.19
Bumbamagara	1.83 ± 0.14	-
Kinigi	1.42 ± 0.13	1.46 ± 0.10
Rwangume	1.59 ± 0.24	-
Rwanshaki	1.17 ± 0.14	1.06 ± 0.14
Victoria	1.20 ± 0.10	1.25 ± 0.20

-Experiment discontinued due to too much sprouting and tuber rotting

Chip color

Chip color was determined basing on the Potato Chips/Snack Food Association (PC/SFA) color card system of 1 to 5 where 1 (light cream) denotes low sugar levels (acceptable) and 5 (very dark brown) denotes very high sugar levels (highly unacceptable). The results for chip color are indicated in Table 12.

The chip color of the varieties ranged from 1 to 5 in all the ambient stores. On average variety 39279.22 had the best score ranging from 1.08 to 1.91 followed by Rwangume with scores ranging from 1.67 to 3.25 while 393385.39 had had a poor color score ranging from 3.33 to 4.67 on average.

Table 12: Variation in chip color of the varieties with the (PC/SFA) color card system

Variety	Chip color (PC/SFA card score)			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	1.08 ± 0.29	1.16 ± 0.39	2.83 ± 1.47	1.92 ± 0.5
393079.4	3.00 ± 0.82	3.00 ± 0.00	4.50 ± 0.55	3.83 ± 0.41
393385.39	4.00 ± 0.00	4.67 ± 0.58	3.30 ± 0.58	4.67 ± 0.58
398208.704	3.00 ± 0.00	3.67 ± 1.64	3.00 ± 1.64	4.00 ± 1.2
Bumbamagara	3.00 ± 0.00	3.00 ± 1.64	3.00 ± 1.64	-
Cruza	3.00 ± 0.00	3.00 ± 0.00	-	-
Kinigi	5.00 ± 0.00	2.50 ± 0.54	3.00 ± 0.00	3.50 ± 0.54
Rwangume	1.67 ± 0.49	3.25 ± 0.45	3.00 ± 0.74	-
Rwanshaki	3.00 ± 0.00	3.50 ± 0.54	3.67 ± 0.81	4.33 ± 0.51
Shangi	3.00 ± 0.00	-	-	-
Victoria	3.00 ± 0.00	3.50 ± 0.55	3.00 ± 1.09	2.50 ± 0.54

-Experiment discontinued due to too much sprouting and tuber rotting

Chip oil absorption (chip oil uptake)

The results for changes in chip oil uptake are indicated in Table 13. The chip oil content ranged from 38.5% to 25.82 % and this is in agreement with the findings of Mellema (2003) which reported that potato chips have an oil absorption that ranging from 30% to 40% (wet basis) that gives the product the unique texture-flavor combination that makes them so desirable. Maximum oil absorption was recorded in Cruza and 393079.4 at 39.16% and 43.90% respectively while minimum oil uptake was recorded in Kinigi at 29.0% to 34.0%. There was a general increase in chip oil uptake in most of the varieties in week 6.

Tubers had an initial low oil absorption because of the high dry matter content (Blenkinsop and Marangoni, 2002). The increase in chip oil uptake with storage time is attributed to the decrease in dry matter content and specific gravity (Rommens et al., 2010). Oil uptake in some varieties does not correlate to dry matter content due to the many factors which have been reported to affect oil uptake into French fries and potato chips, including oil quality, frying temperature and duration, product shape, moisture content, solid content, gel strength, and proteins and the different cellular structures which may have affected oil uptake by influencing either the loss of moisture or the damage done to the original anatomy during processing (Ziaiifar et al., 2008).

Table 13: Changes in chip oil uptake with storage time

Variety	Percentage (%) chip oil uptake		
	Storage time		
	Week 3	Week 6	Week 9
392797.22	34.41 ± 3.70	38.07 ± 4.60	32.46 ± 3.00
393079.4	43.09 ± 6.30	35.31 ± 1.20	33.80 ± 0.60
393385.39	32.88 ± 0.45	36.26 ± 0.15	42.93 ± 2.30
398208.704	29.15 ± 0.11	38.66 ± 2.50	41.52 ± 0.81
Bumbamagara	30.85 ± 0.17	-	-
Cruza	39.16 ± 0.40	-	-
Kinigi	29.49 ± 9.14	34.38 ± 15.7	28.27 ± 7.22
Rwangume	38.55 ± 12.8	35.21 ± 11.34	-
Rwanshaki	31.97 ±0.14	33.23 ± 0.82	28.56 ± 2.69
Victoria	34.43 ± 2.49	37.14 ± 3.47	29.49 ± 5.86

-Experiment discontinued due to too much sprouting and rotting

Chip moisture content

The results for changes in chip moisture content are indicated in Table 14. The chip moisture content ranged between 4.16% and 6.39% on average which is in agreement with the findings of Kampuse, Siljanis and Murniece (2013) who found out that the moisture content of the chips varied between 5.7% and 10.3%. The highest chip moisture was recorded in Victoria at 5.2% to 8.67% and the lowest moisture content recorded in Rwangume at 4.86% to 6.04%. There was a general increase in chip moisture content with tuber storage time especially in the 9th week of storage however for some varieties there was a decrease in moisture content especially in week 6.

Higher chip moisture content leads to reduction in chip texture and affects microbial stability of the final chips (Miranda and Aguilera, 2006).

Table 14: Changes in Chip moisture content with storage time

Variety	Percentage (%) chip moisture content		
	Storage time		
	Week 3	Week 6	Week 9
392797.22	5.33 ± 0.66	3.88 ± 0.30	6.32 ± 1.34
393079.4	4.48 ± 0.37	4.78 ± 0.36	7.60 ± 0.36
393385.39	3.73 ± 0.00	4.60 ± 0.30	6.63 ± 0.42
398208.704	5.31 ± 0.01	4.68 ± 0.12	6.66 ± 0.17
Bumbamagara	6.76 ± 0.25	3.93 ± 0.29	-
Cruza	4.63 ± 0.06	-	-
Kinigi	4.70 ± 0.44	4.70 ± 0.33	7.56 ± 0.21
Rwangume	6.04 ± 1.59	4.86 ± 0.84	-
Rwanshaki	4.30 ± 0.24	4.36 ± 0.44	7.83 ± 0.18
Victoria	5.20 ± 0.06	5.31 ± 0.40	8.67 ± 0.34

-Experiment discontinued due to too much sprouting and rotting

3.4 SENSORY EVALUATION AND CONSUMER ACCEPTABILITY

Potato chips were scored for chip color, texture, flavor and overall acceptability on a 9-point hedonic scale ranging from 1 to 9 where 1 is light color and extremely liked followed by 2 which is light tan and lastly 9 which is very dark brown and extremely disliked as described by Meilgaard et al. (2007).

Color

The results for chip color basing on consumer acceptability are indicated in Table 15. The color score of all the varieties ranged from 1 to 5 during the storage time. On average 39297.22 had the best score ranging from 1 to 1.45 in all the stores followed by Rwangume ranging from 1.5 to 3.25 and Victoria ranging from 2.4 to 3.5. However poor color scores were recorded in 393385.39 with scores ranging from 3.33 to 4.67 and Rwanshaki ranging from 3.25 to 4.25 and Kinigi ranging from 3 to 4.

The poor color scores in some of the varieties are likely to be due to the reaction between the high reducing sugars and a free amino acid or amino group in the Maillard reaction (Fennema, 1996 & Marquez and Anon, 1986). The poor color scores are also likely to be due to the formation of melanoidin pigments (Kumar et al., 2004).

Table 15: Changes in color score with storage time using the consumer panel.

Variety	Chip color consumer acceptability			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	1.00 ± 0.00	1.17 ± 0.38	2.83 ± 1.46	1.45 ± 0.49
393079.4	1.00 ± 0.82	3.00 ± 0.00	4.50 ± 0.54	3.83 ± 0.5
393385.39	4.00 ± 0.00	4.67 ± 0.57	3.3 ± 0.57	4.37 ± 0.60
398208.704	3.00 ± 0.00	3.67 ± 0.60	3.0 ± 0.00	4.20 ± 2.50
Bumbamagara	4.00 ± 0.00	1.50 ± 1.64	1.50 ± 1.60	-
Cruza	4.00 ± 0.00	3.00 ± 0.00	-	-
Kinigi	4.00 ± 0.00	2.80± 0.98	3.25 ± 0.41	3.25 ± 1.72
Rwangume	1.50± 0.67	3.25 ± 0.45	3.00 ± 0.74	-
Rwanshaki	3.00 ± 0.00	3.50 ± 0.55	3.67 ± 0.81	3.70 ± 2.08
Shangi	3.00 ± 0.00	-	-	-
Victoria	2.67 ± 0.52	3.50 ± 0.55	3.00 ± 1.09	2.40 ± 1.11

-Experiment discontinued due to too much sprouting and rotting

Texture

The results for chip texture basing on consumer acceptability are indicated in Table 16. The scores for texture ranged from 1 to 4 in all the varieties. There was a decreasing textural acceptability in all the varieties with storage time. On average Victoria had a good score for texture ranging from 1 to 2.48 in all the stores followed by 398208.704 with a score ranging from 1 to 3.43 and 39297.22 with a score ranging from 1.12 to 2.46. Variety 393079.39 had a poor score for texture ranging from 1.33 to 3.13. The general decrease in texture is likely to be due to the decrease in dry matter content with storage time.

Table 16: Changes in chip texture with storage time

Variety	Chip texture (consumer acceptability)			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	1.12 ± 0.05	1.30 ± 0.12	2.07 ± 0.11	2.46 ± 0.18
393079.4	1.43 ± 0.13	2.40 ± 0.07	3.15 ± 0.03	3.61 ± 0.14
393385.39	1.33 ± 0.08	1.23± 0.06	2.26 ± 0.03	3.13 ± 0.01
398208.704	1.00 ± 0.00	1.06 ± 0.01	1.70 ± 0.09	3.43 ± 0.01
Bumbamagara	2.33 ± 0.05	1.20 ± 1.84	1.00 ± 0.07	-
Cruza	1.00 ± 0.00	1.70 ± 0.06	-	-
Kinigi	1.00 ± 0.00	1.30 ± 0.10	2.10 ± 0.32	2.58 ± 0.17
Rwangume	1.33 ± 0.06	2.10 ± 0.34	2.30 ± 0.44	-
Rwanshaki	1.93 ± 0.01	2.20 ± 0.03	2.60 ± 0.06	2.96 ± 0.06
Shangi	2.16 ± 0.00	-	-	-
Victoria	1.00 ± 0.00	1.20 ± 0.06	1.75 ± 0.09	2.48 ± 0.22

- Experiment discontinued due to too much sprouting and rotting

Flavor

The results for chip flavor basing on consumer acceptability are indicated in Table 17. The score for flavor ranged from 1 to 7.7 in all the varieties during the storage time. There was decreasing flavor acceptability in all the varieties with storage time. On average 392797.22 had the most acceptable flavor score ranging

from 1 to 2.4 followed by Rwangume with an average score ranging from 1.75 to 2.25 during the storage time. On average, 393079.4 had a poorly accepted flavor score ranging from 2.5 to 6.16 followed by 393385.39 with a score ranging from 3 to 4.86. Most of the varieties with a good color score had a good flavor score while those with a poor color score had a poor flavor score because excessive browning yields bitter tasting chips due to formation of melanoidins that are products of Maillard reaction (Lærke and Christiansen, 2005).

Table 17: Change in chip flavor of the varieties with storage time

Variety	Chip flavor (consumer acceptability)			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	1.00 ± 0.00	1.00 ± 0.0	1.16 ± 0.3	2.40 ± 0.6
393079.4	2.50 ± 0.00	3.16 ± 0.3	4.26 ± 0.4	6.16 ± 0.5
393385.39	3.00 ± 0.00	4.33 ± 0.3	4.83 ± 0.5	4.86 ± 0.4
398208.704	3.00 ± 0.00	3.83 ± 0.3	4.00 ± 0.5	4.00 ± 0.3
Bumbamagara	4.00 ± 0.00	3.10 ± 1.7	4.20 ± 1.1	-
Cruza	4.00 ± 0.00	4.00 ± 0.5	-	-
Kinigi	4.00 ± 0.00	3.42 ± 0.6	3.17 ± 0.4	2.45 ± 0.2
Rwangume	2.00± 0.00	1.75 ± 0.6	2.25 ± 0.8	-
Rwanshaki	3.50 ± 0.00	3.90 ± 0.1	3.72 ± 0.3	2.80 ± 0.2
Shangi	3.00 ± 0.00	-	-	-
Victoria	2.00 ± 0.00	2.40 ± 0.5	2.50 ± 0.5	2.65 ± 0.5

- Experiment discontinued due to too much sprouting and rotting

Overall acceptability

The results for overall consumer acceptability are indicated in Table 18. The overall acceptability score ranged from 1.00 to 5.35. Variety 392797.22 was the most acceptable with scores ranging from 1 to 1.37 followed by Rwangume with scores ranging from 1.15 to 1.95 and Victoria with scores ranging from 1 to 1.86. Variety 393385.39 had the least acceptability with scores ranging from 2.5 to 4.93 followed by 393079.4 with scores ranging from 1 to 5.35. Genotype by growing environment interaction, tuber dry matter content, specific gravity, chip texture, bitterness, sweetness, crispiness, are likely to have influenced the overall acceptability

Table 18: Changes in chip overall acceptability with storage time

Variety	Overall acceptability			
	Storage time			
	Week 0	Week 3	Week 6	Week 9
392797.22	1.00 ± 0.0	1.04 ± 0.02	1.22 ± 0.07	1.37 ± 0.17
393079.4	1.00 ± 0.0	2.16 ± 0.08	3.90 ± 0.11	5.35 ± 0.43
393385.39	2.50 ± 0.0	3.23 ± 0.06	4.10 ± 0.13	4.93 ± 0.01
398208.704	3.00 ± 0.0	3.16 ± 0.08	3.60 ± 0.03	4.23 ± 0.06
Bumbamagara	3.00 ± 0.0	1.26 ± 2.04	1.46 ± 2.58	-
Cruza	2.00 ± 0.0	1.93 ± 0.01	-	-
Kinigi	3.16 ± 0.2	3.03 ±0.12	2.83 ± 0.32	3.05 ± 0.83
Rwangume	1.16 ± 0.3	1.15 ± 0.05	1.95 ± 0.67	-
Rwanshaki	3.00 ± 0.0	3.46 ± 0.16	3.60 ± 0.14	1.90 ± 2.20
Shangi	3.00 ± 0.0	-	-	-
Victoria	1.00 ± 0.0	1.30 ± 0.22	1.86 ± 0.29	1.83 ± 0.26

- Experiment discontinued due to too much sprouting and rotting

4.0 SEASON TWO

4.1 STORAGE CONDITIONS

The results of the study indicate that there were differences in temperature and relative humidity within the stores at the different sites.

Table 18: Changes in relative humidity within the stores in season II

	Relative humidity (%) Storage time			
Ambient store	**Week 0**	**Week 3**	**Week 6**	**Week 9**
Bennet	80.01	84.13	86.51	88.27
Kapchorwa	80.67	86.07	87.37	83.99
Mbale	77.97	78.77	79.97	81.60

Table 19: Changes in temperature within the stores in season II

	Temperature˚ C Storage time			
Ambient store	**Week 0**	**week 3**	**Week 6**	**Week 9**
Bennet	15.53	15.82	15.27	15.05
Kapchorwa	18.93	18.65	18.40	18.43
Mbale	23.02	23.24	22.63	22.30

Tables 18 and 19 show that the ambient store in Bennet had the lowest temperature and a high relative humidity while that in Mbale had the highest temperature and low relative humidity. The ambient store in Bennet was more effective in maintaining weight of the tubers and preventing sprouting in comparison to that in Mbale. The ambient store in Kapchorwa maintained better physio-chemical properties such as higher dry matter content, lower reducing sugars and a higher pH in comparison to other ambient stores. The ambient store in Kapchorwa also maintained better processing quality properties like better chip color, higher texture, lower oil uptake and lower chip moisture content in comparison to other ambient stores.

Storage temperature and relative humidity have a great impact on weight loss, dormancy period, physico-chemical properties and potato processing quality. The dormancy period decreases as the temperature increases (Woodell and Olsen, 2009). Weight loss from the tubers is also greater at higher temperatures (Woodell and Olsen, 2009). Very low temperatures lead to accumulation of reducing sugars leading to dark chips and French fries when the potatoes are processed (Olsson et al., 2004).

Weight loss and sprouting

Weight loss

The results of the study indicate that there are differences in the rate of weight loss within the varieties. The highest average percentage weight loss (22.26% and 19.51%) was recorded in Rwangume and 393385.39 respectively, while the least percentage weight loss (2.64%) was recorded in variety 393079.4 as indicated in Table 20.

Table 20: Percentage weight loss of the varieties with storage time.

	Variation in weight loss with storage time Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	0.0 ± 0.0	2.24 ± 0.6	4.40 ± 3.1	5.80 ± 2.9
393079.4	0.0 ± 0.0	0.98 ± 0.8	1.84 ± 0.8	2.64 ± 1.3
393385.39	0.0 ± 0.0	2.91 ± 2.2	12.89 ± 6.6	19.51 ± 5.8
398208.704	0.0 ± 0.0	1.78 ± 1.4	3.94 ± 2.3	8.25 ± 2.6
Kinigi	0.0 ± 0.0	2.36 ± 1.4	5.94 ± 2.7	10.92 ± 5.0
Rwangume	0.0 ± 0.0	5.91 ± 2.5	17.07 ± 9.9	22.26 ± 7.4
Rwanshaka	0.0 ± 0.0	3.24 ± 1.7	5.69 ± 3.4	10.74 ± 5.7
Victoria	0.0 ± 0.0	2.28 ± 1.6	12.87 ± 2.1	18.20 ± 3.8

Sprouting

The results of the study indicate that there are differences in the rate of sprouting within the varieties. Rwangume and Victoria had the shortest dormancy period of about 6 weeks while 398208.704, Kinigi and 393079.4 had a longer dormancy period above 9 weeks as shown in table 21.

Table 21: Percentage sprouting of potato tubers with storage time

	Sprouting Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	0.0 ± 0.0	1.1 ± 0.9	21.67 ± 13.8	80.83 ± 11.9
393079.4	0.0 ± 0.0	0.0 ± 0.0	9.72 ± 1.8	32.77 ± 17.2
393385.39	0.0 ± 0.0	0.0 ± 0.0	11.61 ± 5.4	34.72 ± 6.7
398208.704	0.0 ± 0.0	0.0 ± 0.0	0.00 ± 0.0	16.94 ± 12.5
Kinigi	0.0 ± 0.0	0.0 ± 0.0	1.11 ± 2.0	22.77 ± 8.7
Rwangume	0.0 ± 0.0	8.3 ± 4.3	56.67 ± 8.4	98.00 ± 3.3
Rwanshaka	0.0 ± 0.0	0.0 ± 0.0	29.17 ± 6.4	44.72 ± 8.3
Victoria	0.0 ± 0.0	1.9 ± 0.6	33.61 ± 11.6	86.34 ± 6.1

Decay

There were differences in the rates of decay with in the potato varieties. The highest levels of percentage decay were reported in week 6 and week 9 of storage. Varieties 393385.39 and Rwangume had the highest percentage of decayed tubers while Kinigi and 393079.4 were not affected at all as shown in table 22.

Table 22: Percentage decay of the potato varieties under ambient storage

	Percentage (%) decay Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	0.0 ± 0.0	0.0 ± 0.0	1.11 ±	0.0 ± 0.0
393079.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
393385.39	0.0 ± 0.0	0.0 ± 0.0	3.9 ±	4.7 ±
398208.704	0.0 ± 0.0	0.0 ± 0.0	1.1 ±	0.37 ±
Kinigi	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Rwangume	0.0 ± 0.0	1.9 ±	7.5 ±	2.5 ±
Rwanshaka	0.0 ± 0.0	0.0 ± 0.0	1.1 ±	1.7±
Victoria	0.0 ± 0.0	0.0 ± 0.0	4.4 ±	0.0 ± 0.0

4.2 PHYSICO-CHEMICAL PROPERTIES

Moisture content

The results of the study indicate that the moisture content of the potato varieties was almost constant in the first 3 weeks of storage followed by an increase in moisture content between week 6 and week 9 as shown in table 23. The highest moisture content was recorded in Rwanshaka and Victoria at an average of 81.4% and 80.7% respectively while the lowest moisture content was recorded in 398208.704 and 393385.4 at an average of 78.62% and 79.53% respectively.

Table 23: Variation in moisture content of the potato varieties with storage time

	Percentage (%) moisture content Storage time			
Variety	**Week 0**	**Week 3**	**Week 6**	**Week 9**
392797.22	78.37 ± 0.79	78.80 ± 0.842	80.71 ± 0.76	82.77 ± 0.60
393079.4	78.78 ± 0.63	78.41 ± 0.72	80.51 ± 0.68	81.06 ± 0.63
393385.39	77.68 ± 0.59	77.65 ± 0.79	80.63 ± 0.83	80.83 ± 1.23
398208.704	77.14 ± 0.30	76.72 ± 0.93	78.11 ± 0.83	80.30 ± 0.99
Kinigi	78.63 ± 0.32	78.83 ± 0.87	81.34 ± 0.89	83.19 ± 0.41
Rwangume	79.67 ± 0.64	78.62 ± 0.52	80.26 ± 0.57	81.36 ± 0.42
Rwanshaki	81.01 ± 0.35	80.91 ± 0.59	81.43 ± 0.48	82.30 ± 1.03
Victoria	79.64 ± 0.34	79.41 ± 0.65	81.36 ± 0.61	82.48 ± 0.44

Dry matter content

Dry matter content was fairly constant in the first 3 weeks of storage followed by a decrease in dry matter content of the potato varieties in week 6 and week 9 as shown in Table 24. The highest dry matter content was recorded in 398208.704 and 393385.4 at an average of 21.9% and 20.8%, respectively while the lowest dry matter content was recorded in Rwanshaka and Victoria at an average of 19.2% and 18.5% respectively.

Table 24: Changes in dry matter content of the potato varieties with storage time

	Percentage (%) dry matter content Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	18.63 ± 0.7	21.20 ± 0.8	19.29 ± 0.7	17.23 ± 0.6
393079.4	21.59 ± 0.6	21.59 ± 0.7	19.49 ± 0.7	18.94 ± 0.6
393385.39	22.32 ± 0.6	22.35 ± 0.8	19.37 ± 0.8	19.17 ± 1.2
398208.704	21.88 ± 0.3	23.28 ± 0.9	21.89 ± 0.8	19.70 ± 0.9
Kinigi	20.04 ± 0.3	21.17 ± 0.9	18.70 ± 0.9	16.81 ± 0.4
Rwangume	18.00 ± 0.6	21.38 ± 0.5	19.74 ± 0.6	18.64 ± 0.4
Rwanshaka	17.66 ± 0.4	19.09 ± 0.6	18.57 ± 0.5	17.70 ± 1.0
Victoria	19.36 ± 0.3	20.59 ± 0.6	18.64 ± 0.6	17.52 ± 0.4

pH

There was an increase in pH in week 3 and a drop in pH in week 6 week and week 9 of storage. Table 25 shows that the highest pH levels were recorded in Kinigi and 393079.4 at an average of 6.25 and 6.24 respectively while the lowest pH levels were recorded in 398208.704 and Victoria at an average of 6.09 and 5.99 respectively.

Table 25: Variation in pH of the varieties with storage time

	pH Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	6.03 ± 0.02	6.16 ± 0.01	6.18 ± 0.02	6.26 ± 0.03
393079.4	6.22 ± 0.01	6.33 ± 0.22	6.22 ± 0.16	6.22 ± 0.06
393385.39	6.03 ± 0.03	6.19 ± 0.05	6.17 ± 0.01	6.07 ± 0.07
398208.704	6.06 ± 0.03	6.11 ± 0.03	6.11 ± 0.08	6.11 ± 0.09
Kinigi	6.08 ± 0.05	6.37 ± 0.05	6.27 ± 0.05	6.29 ± 0.005
Rwangume	5.94 ± 0.07	6.20 ± 0.05	6.21 ± 0.04	6.12 ± 0.03
Rwanshaka	6.22 ± 0.05	6.29 ± 0.09	6.21 ± 0.09	6.22 ± 0.04
Victoria	5.92 ± 0.07	5.99 ± 0.02	6.08 ± 0.06	5.99 ± 0.08

Titratable acidity

The results of the study show that there was a decrease in titratable acidity between week 0 and week 3 followed by an increase in titratable acidity in week 6 and week 9. Table 26 shows that the highest levels of titratable acidity were recorded in variety Kinigi and 393385.39 at an average of 0.037 and 0.036, respectively while the lowest levels of titratable acidity were recorded in Rwanshaka and Rwangume at an average of 0.03 and 0.031, respectively.

Table 26: Variation in titratable acidity of the potato varieties with storage time

	Titratable acidity Storage time			
Variety	**Week 0**	**Week 3**	**Week 6**	**Week 9**
39297.22	0.0558± 0.0074	0.0272± 0.0051	0.0203± 0.0018	0.0410± 0.0155
393079.4	0.0416± 0.0067	0.0252± 0.0036	0.0222± 0.0029	0.0446± 0.0175
393385.39	0.0460± 0.0045	0.0267± 0.0043	0.0304± 0.0038	0.0417± 0.0072
398208.704	0.0484± 0.0033	0.0246± 0.0040	0.0246± 0.0061	0.0448± 0.0110
Kinigi	0.0533± 0.0279	0.0270± 0.0063	0.0225± 0.0029	0.0449± 0.0135
Rwangume	0.0357± 0.0028	0.0302± 0.0064	0.0200± 0.0053	0.0466± 0.0090
Rwanshaka	0.0378± 0.0064	0.0303± 0.0038	0.0197± 0.0057	0.0448± 0.0112
Victoria	0.0403± 0.0045	0.0294± 0.0040	0.0254± 0.0032	0.0432± 0.0120

Reducing sugars

The results of the study indicate that there was a general increase in the reducing sugar content of the potato varieties with increase in storage time as shown in Table 27. Varieties 398208.704 and Victoria had the highest level of reducing sugars at an average of 0.084% and 0.083%, respectively while Rwanshaka and Rwangume had the lowest level of reducing sugars at 0.045% and 0.054%, respectively.

Table 27: Variation in percentage reducing sugar content of the potato varieties with storage time

	Percentage (%) reducing sugars Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	0.023 ± 0.003	0.072 ± 0.040	0.082 ± 0.040	0.077 ± 0.039
393079.4	0.010 ± 0.004	0.041 ± 0.030	0.075 ± 0.050	0.091 ± 0.030
393385.39	0.004 ± 0.001	0.089 ± 0.060	0.048 ± 0.030	0.081 ± 0.050
398208.704	0.019 ± 0.001	0.058 ± 0.020	0.115 ± 0.060	0.083 ± 0.040
Kinigi	0.006 ± 0.004	0.049 ± 0.028	0.060 ± 0.028	0.127 ± 0.068
Rwangume	0.011 ± 0.002	0.033 ± 0.022	0.063 ± 0.039	0.109 ± 0.092
Rwanshaka	0.007 ± 0.001	0.073 ± 0.035	0.054 ± 0.024	0.047 ± 0.022
Victoria	0.021 ± 0.003	0.111 ± 0.035	0.081 ± 0.047	0.121 ± 0.040

4.3 PROCESSING QUALITY

Chip color

There was a general increase in chip color of the varieties with increase in storage time as shown in Table 28. Varieties Rwangume and 39279.22 had the best color score (lowest score) with an average score of 2.0 and 1.9, respectively while 398208.704 and Victoria had a poor chip color (high score) with an average score of 3.8 and 3.5, respectively.

Table 28: Variation in chip color of the potato varieties with storage time

	Chip Color Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	1.33 ± 0.5	2.33 ± 0.7	2.44 ± 0.8	1.88 ± 0.7
393079.4	1.33 ± 0.5	2.77 ± 0.8	3.33 ± 1.0	3.22 ± 0.6
393385.39	1.66 ± 0.5	3.00 ± 0.7	2.67 ± 0.5	3.67 ± 0.7
398208.704	2.66 ± 0.5	4.22 ± 0.8	4.88 ± 0.3	3.44 ± 0.5
Kinigi	1.30 ± 0.5	2.20 ± 0.6	2.66 ± 0.7	4.00 ± 0.6
Rwangume	2.30 ± 0.5	1.40 ±	2.4 0 ± 0.8	2.00 ± 0.6
Rwanshaka	1.80 ± 0.6	2.80 ±	2.00 ± 0.8	2.10 ± 0.6
Victoria	2.30 ± 0.5	4.30 ±	3.40 ± 2.0	4.10 ± 0.3

Chip texture

There was an increase in chip texture between week 0 and week 3 followed by a general decrease in chip texture of the varieties between week 3 and week 9 as shown in Table 29. Varieties 398208.704 and 393385.39 had the highest chip texture at an average of 0.94 and 0.85 kg, respectively while Rwanshaka and Kinigi had the lowest chip texture at an average of 0.59 and 0.66, kg respectively.

Table 29: Variation in chip texture of the potato varieties with storage time

	Chip texture Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	0.77 ± 0.05	0.84 ± 0.10	0.61 ± 0.12	0.67 ± 0.07
393079.4	0.73 ± 0.10	0.89 ± 0.23	0.78 ± 0.13	0.71 ± 0.06
393385.39	0.87 ± 0.09	0.98 ± 0.16	0.86 ± 0.10	0.72 ± 0.25
398208.704	0.90 ± 0.05	1.06 ± 0.21	1.10 ± 0.10	0.72 ± 0.09
Kinigi	0.67 ± 0.10	0.74 ± 0.12	0.57 ± 0.13	0.45 ± 0.05
Rwangume	0.83 ± 0.13	0.91 ± 0.10	0.52 ± 0.08	0.57 ± 0.05
Rwanshaka	0.67 ± 0.05	0.62 ± 0.12	0.56 ± 0.13	0.52 ± 0.10
Victoria	0.73 ± 0.05	0.74 ± 0.08	0.69 ± 0.09	0.67 ± 0.10

Chip oil uptake

There was a general decrease in chip oil uptake of the varieties between week 0 and week 3 followed by an increase in chip oil uptake in all the varieties in the 6th and 9th week of storage. Table 30 shows that the highest oil uptake was recorded in 398208.704 and Rwanshaka at an average of 42.22% and 42.00% respectively while minimum oil uptake was recorded in Kinigi at an average of 35.27%.

Table 30: Variation in chip moisture content of the potato varieties with storage time

	Chip oil uptake Storage time			
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	47.39 ± 1.1	39.99 ± 0.9	42.14 ± 0.8	44.33 ± 1.2
393079.4	47.71 ± 0.4	40.28 ± 4.1	36.95 ± 4.0	40.59 ± 1.4
393385.39	44.99 ± 0.7	35.64 ± 4.3	37.52 ± 1.6	37.47 ± 2.8
398208.704	51.59 ± 0.5	36.77 ± 5.8	38.91 ± 4.9	44.96 ± 5.1
Kinigi	30.477 ± 1.5	39.34 ± 1.9	42.85 ± 3.5	42.6 ± 1.1
Rwangume	46.90 ± 1.2	35.99 ± 4.2	39.40 ± 4.9	42.94 ± 3.6
Rwanshaka	54.38 ± 3.1	43.24 ± 3.5	37.73 ± 3.4	35.83 ± 2.4
Victoria	43.80 ± 1.5	42.52 ± 1.2	43.31 ± 5.2	46.44 ± 1.5

Chip moisture content

There was a general decrease in chip moisture content in the first 3 weeks of storage followed by an increase in chip moisture content of the potato varieties during the last weeks of storage. The highest chip moisture content was recorded in Kinigi and 393079.4 at an average of 5.09% and 4.96%, respectively while the lowest chip moisture content was recorded in 39297.22 and 398208.704 at an average of 3.78% and 4.09%, respectively (Table 31).

Table 31: Variation in chip moisture content of the potato varieties with storage time

Percentage (%) chip moisture content Storage time				
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	4.70 ± 0.32	2.89 ± 0.30	3.16 ± 0.74	4.38 ± 0.57
393079.4	5.69 ± 0.15	4.51 ± 0.31	3.65 ± 1.25	5.99 ± 1.28
393385.39	5.66 ± 0.13	4.34 ± 0.42	4.23 ± 0.44	4.38 ± 0.86
398208.704	3.27 ± 0.18	2.67 ± 0.33	4.43 ± 0.87	6.00 ± 1.30
Kinigi	5.58± 0.15	4.02 ± 0.23	4.77 ± 1.01	6.00 ± 0.73
Rwangume	5.40 ± 0.10	4.31 ± 0.27	6.16 ± 0.97	4.53 ± 0.62
Rwanshaka	3.42 ± 0.16	3.12 ± 0.25	6.08 ± 1.35	6.52 ± 1.20
Victoria	6.33 ± 0.14	5.47 ± 0.36	5.38 ± 0.78	5.1 ± 0.28

4.4 SENSORY EVALUATION AND CONSUMER ACCEPTABILITY

The sample potato chips were scored for chip color, texture, flavor, and oiliness to determine their level of acceptability on a 9-point hedonic scale ranging from 1 (extremely like) to 9 (extremely dislike) as described by Meilgaard et al., 2007. The results of the study indicated that there was a general decrease in overall acceptability of the potato chips from all the varieties with increase in storage time. Table 32 shows that varieties 392797.22, Kinigi, Rwanshaka and Rwangume were the most acceptable with an average color score of 2.82, 2.63, 2.90 and 3.01, respectively while 398208.704 and Victoria were the least acceptable varieties with an average score of 3.86 and 3.64, respectively.

Table 32: Variation in overall acceptability of the potato varieties with storage time

Variation in Overall acceptability Storage time				
Variety	**week 0**	**week 3**	**week 6**	**week 9**
39297.22	2.50 ± 0.01	2.85 ± 0.47	3.32 ± 0.19	2.62 ± 0.86
393079.4	3.63 ± 0.16	3.51 ± 0.26	3.42 ± 0.86	3.76 ± 0.58
393385.4	2.63 ± 0.14	3.72 ± 0.23	3.30 ± 0.97	3.60 ± 0.65
398208.7	3.16 ± 0.03	3.95 ± 0.09	4.84 ± 0.7	3.50 ± 0.50
Kinigi	1.80 ± 0.15	3.07 ± 0.15	3.25 ± 0.32	3.60 ± 0.74
Rwangume	3.03 ± 0.09	2.55 ± 0.09	3.45 ± 0.64	2.30 ± 0.12
Rwanshaka	2.26 ± 0.07	2.84 ± 0.07	3.38 ± 0.66	3.27 ± 0.51
Victoria	3.30 ± 0.05	3.88 ± 0.05	3.45 ± 0.87	3.97 ± 0.55

5.0 RECOMMENDATIONS

Only varieties with dormancy of two months or greater are suitable for storage. All varieties in this study had sufficient dormancy lengths, with the exception of Shangi. Varieties 39279.22, Rwangume and Kinigi should be used as premium processing varieties for the potato industry owing to their relatively low reducing sugars, good chip color and their high overall consumer acceptability.

Basing on the difference in temperature and relative humidity within the stores, together with the genetic makeup of the potato varieties, the potatoes in the Mbale ambient store should be sold off at a maximum of 6 weeks while those in Kapchorwa and Bennet should be sold off at a maximum of 9 weeks if they are to have better processing quality characteristics.