Misr J. Ag. Eng., 26(1): 385- 408 PROCESS ENGINEERING

PHYSICAL CHARACTERISTICS AND CHEMICAL PROPERTIES OF POTATO TUBERS UNDER DIFFERENT STORAGE SYSTEMS

Gamea, G. R.*; Abd El-Maksoud, M.A.*; Abd El-Gawad,A.M.**

ABSTRACT

Physical characteristics and some major chemical properties of potato tubers (Diamond and Santana varieties) at fresh, cured and stored in two storage systems stages were investigated. Nawalla traditional storage system at 16$\pm$3^oC; 84% relative humidity and Cold storage system at 4^oC; 90 RH were used in the investigation. The storage period after curing stage was 75 days. This period was divided into 3 sub periods every 25 days. Physical characteristics included physical dimensions, shape, weight analysis, actual and calculated volumes, particle and bulk densities, , surface area, particle density, repose angle, static coefficient of friction on different surfaces (rubber, steel and wood), firmness, penetration resistance, impact height and the percentage of bruised tubers due to free falling on steel. While, chemical properties included the changes of moisture content and sugar concentration of tubers. Statistical and regression analysis were conducted to the obtained data.

INTRODUCTION

The potato (Solanum tuberosum, L.), ranks the first position for export and the second position in acreage among vegetable crops in Egypt. Its total area in year 2000 was 75 million hactar. with a total production of 1.76 million tons (Ministry of Ag. And Rec. 2001-2004). Due to the increasing demand of consumers and foreign importers on this important crop, special attention should be given to increase its yield and quality. This could be achieved through improving its post-harvest agricultural operations during handling and storage. Potatoes are stored not only for seeds but also for different purposes.

* Assoc. Prof. of Ag. Eng. Dep. Fac. Of Ag. Menoufiya U.
** Eng. of Ag. Eng. Res. Center

In the same time, the method of storage and its conditions has major implications for the quality of the product and for losses due to pests and diseases. During handling operations, many external factors affect tubers as bruising;

Mohsenin (1986) defined bruising as a damage to pant tissue of potato tuber by external forces causing physical changes and chemical reactions. The blue- black or gray-black discoloration associated with black spot bruise is a result of oxidation of tyrosine by poly phenol oxidizes. Similarly, during storage sprouting, disease, water loss, sugar built up and greening could be happened and controlled. Studying both physical characteristics and properties of tubers and the major chemical properties sand also the effect of the storage method on these properties will be one side of solving the question of the quality and quantity of potato tubers.

Suliman et al., 1999 concluded that the shape of Alpha is oval while Sponta potato variety is long. According to ASAE, STANDERS, 1998 large potatoes > 89mm diameter with a low specific gravity of 1.050 g/cm^3 reach the smaller bulk density value. Small potatoes < 51 mm diameter with a high specific gravity of 1.10 g/cm^3. Smith, 1977 mentioned that the high specific gravity of potatoes are preferred for potato chips, while the low gravity tubers are preferred for canning. This because they fall a part less during processing. He also confirmed that temperature and humidity of storage influence on specific gravity. Baritelle, 1997 stated that higher specific gravity potato tubers are less resistance to bruising.

Mohsenin, 1986 clarified that the knowledge of the surface area of vegetables and fruits is important in many aspects like heat transfer studies in heating and cooling processes. Many methods (numerical and experimental) are recommended for measuring surface area for potato tubers. The appropriate technique is by peeling the individual tuber and projecting or tracing peels on a white paper . Then the traced surfaces are scanned through a scanner and computer program (written by C^{++}) Similar techniques were achieved by Matouk (2002) and Alhamdan et al. (2003) on individual date fruits.

Rastovski and Van, 1981 concluded that the dropping heights for potato tubers when processed must be limited from 30 to 40 cm with conveyor speed not exceed 40m/min for minimizing tuber damage .Smith, 1977 pointed out that cured potato tubers for 8-12 days immediately after harvesting under warm moist conditions lost 7.54 % of their weight during 7 months storage period. Those which were not cured had a weight loss of 9.33 %.

The main objectives of this study are:

1-Assigning some major physical characteristics and chemical properties of two Egyptian fresh potato varieties (Santana and Diamont).

2-Studying the effect of storing in both cold store and traditional one on potato tubers properties.

MATERIALS AND METHODS

Two randomized samples of potato tubers (Diamond and Santana) varieties were taken carefully from a private farm to the laboratory of Ag.Eng.laboratory, Fac.of Ag., Minufiya University during summer 2005 for carrying out all measurements related to physical characteristics and chemical properties during the following stages :fresh, cured and stored.

The experimental procedures of this study involved three stages:

-The first stage included all measurements and calculations of tubers properties during harvesting day (fresh tubers).

-The second stage included all measurements and calculations of tubers properties after curing for15 days from harvesting day. Curing treatments were done under room temperature 24^{o}C.

-The third stage started when potato tubers stored in two widely distributed storage systems:

1-Nawalla traditional storage system at 16$\pm$ 3^{o}C; 84% relative humidity. Usually, this store was built from perforated mud bricks or normal bricks under shade, where potato are placed in piles (2.2m width, 5.2m length, and 1.5m height). The piles were covered with 30cm thickness rice straw (dusted with insecticide carbonyl powder 5%) to protect tubers from light and insects. Piles were placed 50cm in between and 25 cm from Nawalla wall .The internal dimensions of this storage system was 5.4 m width , 6.6 m length and 2.6m height. It had upper and lower openings (20cm×20cm), which was covered with meshes for protection and ventilation requirements.

2-Cold storage system at 4°C and 90% relative humidity. It is normal isolated storage method. Its internal dimensions are 8.5m width, 13.5m length and 4.5m height. It is built from thermal bricks and isolated walls. Potato packages are stacked in rows at 3m width, 11.5m length and 4m height. Potato stacks are placed 90cm in between and 60cm from the cold wall. The storage time of the two varieties of potato tubers within the two systems was divided into 3 periods, 25 days each. All experimental measurements related to physical characteristics and chemical properties were taken every 25 days storage time.

A digital slide caliper of accuracy of 0.01mm was used for measuring the three axis of tuber (the major axis as tuber length (L-mm), the intermediate diameter as tuber width (D-mm), and the thickness of tuber (T-mm)). The weights of tubers were conducted using an electrical digital balance model (ACCULAB-LT 3200, Cole parmer, Chicago) with maximum capacity of 3200 grams and 0.01 gram accuracy.

Shape index of the measured samples was calculated according to (Ismail.1988) as follows:

$$I = \frac{L}{\sqrt{DT}}$$

Where:

I = shape index; **L** = length of tuber, mm;

D = width of tuber, mm and **T** = thickness of potato tuber, mm.

The obtained data were compared with the recommended limits and classified into two main classes (spherical and oval shapes) to specify the tubers according the calculated shape index for each variety of potato tubers .($I \leq 1.5$ for spherical while, $I \geq 1.5$ for oval shape).

The actual volume (V-mm^3) of potato tubers was measured by immerging each tuber instantaneously in 500 or 1000ml measuring cylinder filled with tap water to a fixed limit, the displaced water (W-g) was checked up also by a 250ml pipette with 0.1cm^3 accuracy and determined according the following equation:

$$V_{act} = \frac{W}{S_p}$$

Where:

V = actual volume of individual tuber, mm^3,

W= weight of displaced water, g;

S_p= specific density of water g/mm^3.

The nearest mathematical expression for the volume of potato tubers of the two varieties was taken according Mohsenin, 1986 as follows:

$$V_{cal} = (\pi / 6)(L.D.T)$$

Where:

V$_{act}$ = calculated volume of individual tuber, mm^3;

L= length of potato tuber, mm;

T= thickness of potato tuber, mm. and

D= width of potato tubers, mm.

Particle density of potato tubers was calculated considering the actual volume of the individual potato tuber and its weight as follows:

$$P_d = \frac{W}{V_{act}}$$

Where:

P$_d$ = particle density of the individual tuber, g/cm^3;

W = weight of potato tuber, g and

V$_{act}$= actual volume of the individual potato tuber, cm^3.

Bulk density of potato tubers was evaluated by dividing the weight of a bulk of tubers on its estimated volume. In this case, the volume was measured using a density wood box. It has the dimensions of 30×30×30 cm^{3}where a bulk of tubers was put in the box, then the box was vibrated to the tubers incorporation.

Surface area of potato tubers was measured by peeling the tuber and tracing it on a white paper Then, traced surface was measured by using scan-processing methods with computer programs (1 photo express and Auto-cad programs having accuracy up to 10^{-10}). The test procedures were done according to Matouk, et al., 2002.

Potato tubers repose angle for the two varieties was measured by pouring a knowing potato bulk from a recommended height under gravity into repose angle apparatus according to Ismail, 1991.

Static coefficient of friction of potato tubers was measured on different surfaces rubber, steel and wood according to Abd El Mageed and Abd Alla, 1994. Experiments were conducted at harvesting day (fresh potatoes), after 15 days curing period and at 25,50 and75 days during storage time in both Nawalla traditional storage method and Cold storage systems for the potato tubers of the two varieties. A digital penetration resistance meter (FGN-50) with accuracy of 0.1N was used for measuring both potato tubers firmness and penetration resistance. Firmness was measured by pressing a flat end of appropriate plunger with diameter of 12.22 mm into each tuber of the concerned sample to a depth of 8mm. While, appropriate plunger with con end (45 angle con) was used to measure penetration resistance at 8mm depth into each tuber.

Impact height and measuring the related bruises of tubers were conducted by free dropping of each sample of the same weight from heights ranged from 0.30 to 0.90m on steel surface using a particular free falling table Potato tubers of the same weight (g) were tested during fresh period after curing period and at 25, 50 and 75 days storage periods in both Nawalla and Cold storage systems for the two varieties. The percentages of the bruised tubers as affected by both falling height and by weight due to free falling were estimated. To detect the bruising in tuber the samples were taken to treated with a detecting solution (catechol) - Boswall, 2002.The mean values of ten replicates as a percentage of impact damage were recorded.

Moisture content (w.b%) of tubers was determined according to AOAC (2003).. A refract meter with an accuracy of 0.5 prix No. was used for measuring sugar concentration in tuber sample at all stages of the experiment.

RESULTS AND DISCUSSIONS

Four hundred potato tubers of both diamond and Santana varieties were used for determining physical and chemical characteristics for fresh; cured and stored tubers at equal periods of times in two popular Egyptians storage systems.

Main dimensions

The statistical analysis of the variations of the main measurements for length "L"; width "W" and thickness "T" in mm of both Santana and Diamont fresh tubers are shown in Table(1).

The analyzed data in table (1) show that a high dispersion was found in Diamont tubers with respect to length, while the difference between the investigated varieties was not significant for both width and thickness of

Table (1): Descriptive Statistics of some physical measurements for fresh potato tubers (Diamont and Santana varieties).

Properties	Varieties	Average $\bar{X}$	Range, Max - Min	S.D. (δn-1)	S.E. ($S_{\bar{x}}$)	C.V. %	Conf. L	test
Tuber length, mm	Diamont	75.56	98.38 –60.97	9.54	1.74	12.63	3.56	1.94
	Santana	83.28	107.28 – 63.99	12.24	2.23	14.69	4.57	
Tuber width, mm	Diamont	55.07	68.83 – 45	6.93	1.26	12.58	2.59	5.54
	Santana	68.59	83.17 – 58.94	6.48	1.18	9.45	2.42	
Tuber thickness, mm	Diamont	46.75	55.16 – 38.25	4.58	0.83	9.81	1.71	2.51
	Santana	51.24	64.78 – 42.78	5.30	0.96	10.36	1.98	
Sphericity, %	Diamont	76.298	89.83 – 65.95	5.72	0.738	7.49	1.477	4.05
	Santana	82.31	93.55 – 69.09	5.78	0.747	7.03	1.495	
Shape index	Diamont	1.49	1.86 – 1.18	0.16	0.03	11.27	0.06	1.8
	Santana	1.40	1.74 – 1.19	0.14	0.02	10.52	0.055	
Tuber weight, g	Dimont	109.56	216.49 – 56.66	37.49	6.61	34.21	13.5	3.98
	Santana	174.13	314.24 - 98.15	52.74	9.62	30.28	19.6	

Where: S.D. - standard deviation; S.E –standard error; C.V - Coefficient of variance Conf. L. - Confidence Level (95.0%) T tabulated = 1.96 the tubers. The same table clears that Santana tubers varieties were higher in the main dimensions in averages and range.

Figure (1) indicates the changes in the main dimensions during storage periods in the Cold and Nawalla storage systems.
A grading decrement was noticed in the main dimensions of potato tubers for the two varieties by increasing storage time. Also the small changes in potato tubers dimensions were happened when stored in Cold storage system.. Statistical linear regression analyses were conducted to the experimental measured data to observe the effect of storage time on the main dimensions of potato tubers. The equations were as follows:

Diamont variety	:	$L_c = -0.0567\ ST + 73.677$	$R^2 = 0.93$
	:	$L_n = -0.0796\ ST + 73.385$	$R^2 = 0.99$
Santana variety	:	$L_c = -0.0743\ ST + 81.492$	$R^2 = 0.99$
	:	$L_n = -0.1034\ ST + 81.208$	$R^2 = 0.99$
Diamont variety	:	$W_c = -0.0326\ ST + 54.281$	$R^2 = 0.97$
	:	$W_n = -0.0482\ ST + 53.96$	$R^2 = 0.99$
Santana variety	:	$W_c = -0.0378\ ST + 67.718$	$R^2 = 0.99$
	:	$W_n = -0.0428\ ST + 67.58$	$R^2 = 0.98$
Diamont variety	:	$T_c = -0.0338\ ST + 45.939$	$R^2 = 0.99$
	:	$T_n = -0.0512\ ST + 45.842$	$R^2 = 0.99$
Santana variety	:	$T_c = -0.0338\ ST + 50.64$	$R^2 = 0.99$
	:	$T_n = -0.0383\ ST + 50.561$	$R^2 = 0.99$

Where:

ST = storage time, days ,

L_c, **L_n** = length ,mm of stored tubers in Cold and Nawalla storage systems,

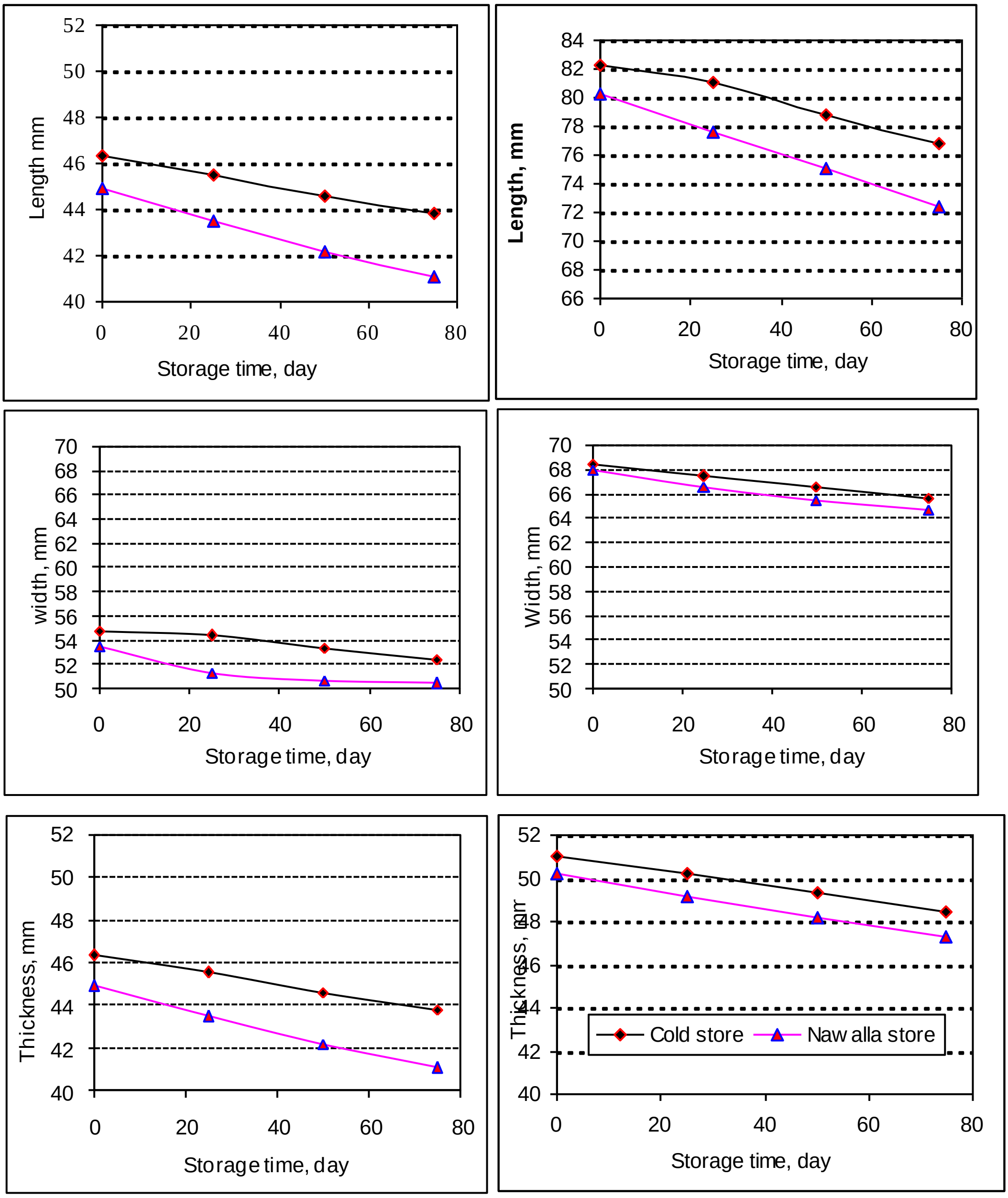
W_c, **W_n** = width, mm of stored tubers in Cold and Nawalla systems,

T_c, T_n = Thickness , mm of stored tubers in Cold and Nawalla storage systems

The obtained equations clarified that tuber dimensions were inversely proportional with storage time for the two varieties.

<u>Shape index</u>

Figure (2) represents the frequency distribution curves and the average value of shape index for the individual fresh tubers of the two varieties. It is clear according to Ismail,1988 that the fresh tubers of the two varieties may be considered as round to oblong group. The percentages of the



a- Diamont variety b- Santana variety

Figure (1): Changes in potato tubers dimensions during storage periods in Cold and Nwalla storage systems after curing.

classes of fresh tubers shape were 54; 73% spherical and 46; 27% oval for Dimont and Santana tubers.

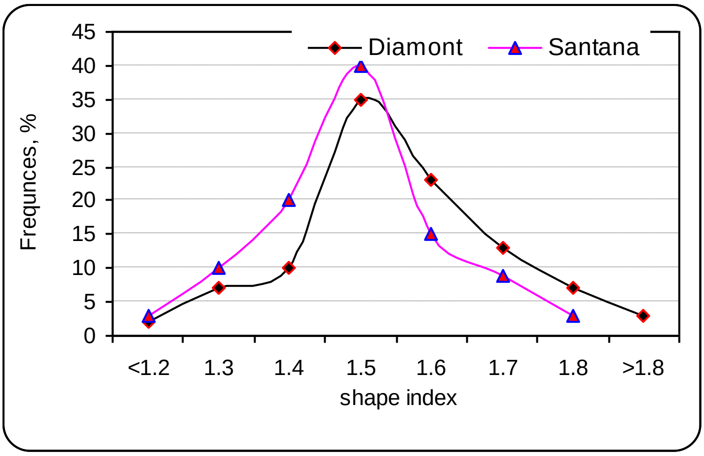
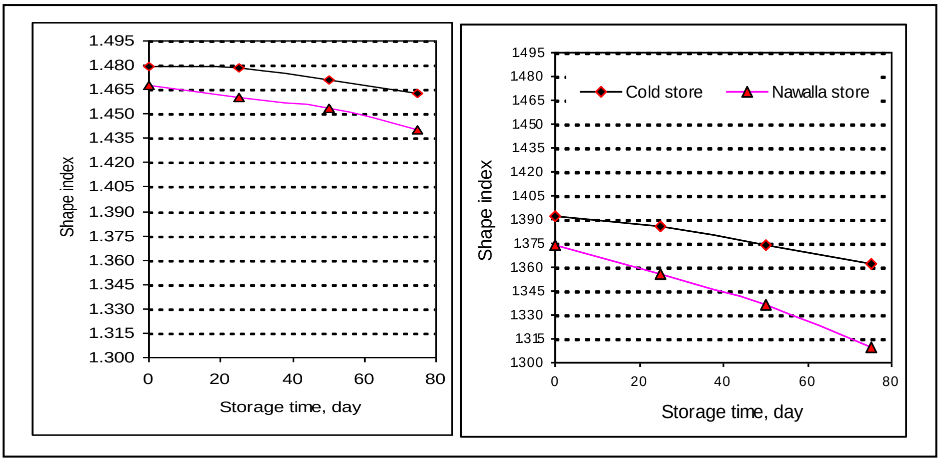


Figure (2): Frequency distribution curves of shape index for the investigated fresh potato tubers (harvesting day).

Sphericity

Also, it is clear from data in table (1) that the difference between the two varieties was not significant with respect to sphericity. According to storing tubers in the two storage systems a small changes were happened in the shape index of tubers of the two varieties as indicated in figure (3).



a-Diamont variety b- Santana variety

Figure (3): Changes in potato tubers shape index during storage period in Cold and Nawalla storage systems.

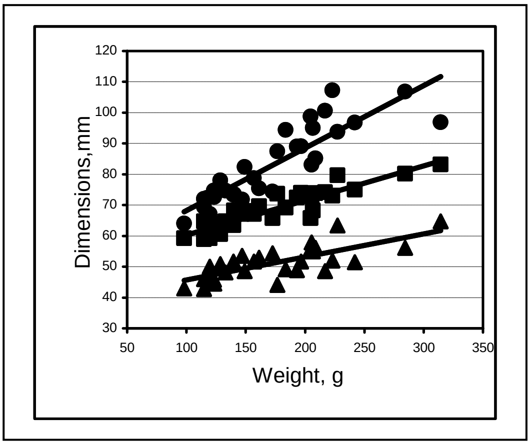
Weight of potato tubers

It can be seen from table (1) that the fresh potato varieties varied greatly in tuber weight as it ranged from (98.18 to 314.24g) and (56.66 to 216.49g) for Santana and Dimont respectively. The mean values and confidence limits were (174.13$\pm$19.69g) and (109.56$\pm$13.52g) for Santana and Dimont varieties. Multiple regression equations were determined to describe the relationship between the weight of tubers and its main dimensions for the two varieties as follows:

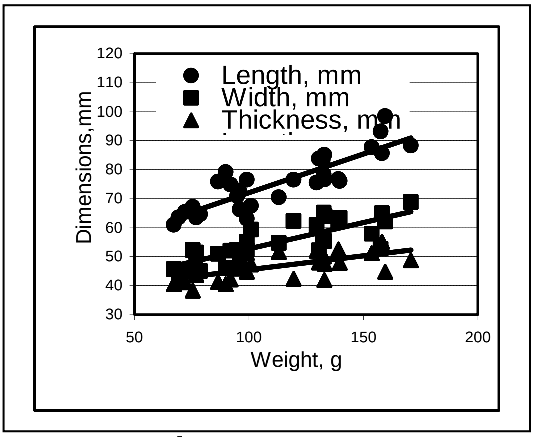
Dimont varieties: $\mathbf{W} = 1.65\mathbf{L}+1.85\mathbf{D}+2.44\mathbf{T}-228.3$ $\qquad$ $\mathbf{R}^2 = 0.97$

Santana varieties: $\mathbf{W} =1.82\mathbf{L}+3.3\mathbf{D}+2.66\mathbf{T}-3473.2$ $\qquad$ $\mathbf{R}^2 = 0.94$

The equations show that the dimensions of fresh potato tubers varieties were directly proportional with its weight for both varieties. This logical result was confirmed as shown in figure (4).



a- Diamont variety



b-Santana variety

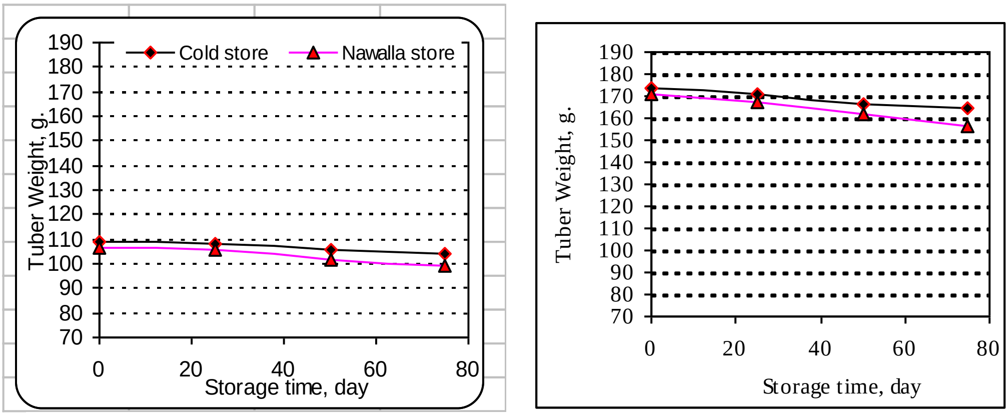
The weight of potato tubers had a negative relationship with storage time in both Nawalla and Cold storage systems as shown from obtained linear regression equations and figure (5).

Diamont	:	$W_{cold} = -0.1774\ ST + 108.51$	$R^2 = 0.97$
variety	:	$W_{Nawalla} = -0.2425\ ST + 109.07$	$R^2 = 0.96$
Santana	:	$W_{cold} = -0.3263\ ST + 173.55$	$R^2 = 0.97$
variety	:	$W_{Nawalla} = -0.4098\ ST + 174.24$	$R^2 = 0.96$

Where:

$W_{cold;Nawalla}$: is weight, g in Cold and Nawalla storage systems;

ST : is the storage time, days.



a-Dimont variety b-Santana variety

Figure (5): Changes in potato tubers weight during storage period in the two storage systems (Cold and Nwalla)

Volume of tubers

It is observed from table (2) that both the changes in main dimensions and weight of potato tubers with storage time as demonstrated before clarify the logic fact that volume also decreases with storage time for both its actual and calculated forms. In this regard.

Table (2): Statistical index of some physical characteristics for the investigated varieties of fresh potato tubers:

Properties	Varieties	Average $\bar{X}$	Range, Max - Min	S.D. (δn-1)	S.E. ($S_{\bar{x}}$)	C.V. %	Conf. L	T Stat
Actual volume, cm^3	Diamont	103.6	186.5 - 60	34.35	6.271	33.15	12.82	3.58
	Santana	159.5	275 - 88	51.09	9.328	32.03	19.07	
Calculated volume, cm^3	Diamont	104.32	186.42 – 62.59	34.39	6.279	32.96	12.84	3.61
	Santana	159.87	275.21 – 85.21	49.82	9.096	31.16	18.6	
Particle Density, g/cm^3	Diamont	1.096	1.26 – 0.968	0.06	0.0109	5.48	0.022	0.13
	Santana	1.099	1.221 – 0.924	0.067	0.0122	6.114	0.025	
Bulk Density, kg/m^3	Diamont	681.5	688 – 672	64.81	2.52	9.5	3.44	5.59
	Santana	658.3	668 – 653	65.16	2.63	9.9	3.69	
Measured Surface area, mm^2	Diamont	134.45	198.88 – 89.92	26.19	3.381	19.48	6.76	4.38
	Santana	168.88	259.12 – 101.5	34.45	4.485	20.4	8.98	
Calculated Surface area, mm^2	Diamont	110.37	164.35 – 78.63	21.48	2.77	19.46	5.55	4.98
	Santana	142.91	220.01 – 85.31	29.01	3.77	20.3	7.56	
Repose angle	Diamont	31° 33'	35° 28°	2.37	0.53	7.51	1.11	3.51
	Santana	34° 50'	37° 30°	2.57	0.61	7.38	1.28	

Particle and bulk density of potato tubers

It is observed from table (2) that the average particle and bulk densities of fresh potato tubers was 1.096; 1.099 g/cm^3 and 681.5; 658.3 kg/cm^3 for Diamont and Santana varieties.

Surface area

The analyzed data in Table (2) show that the average measured surface area was 134.45 and 168.8cm^3 for fresh potato tubers Diamnot and Santana varieties respectively. Linear regression analysis were applied to the data for the individual tubers with respect to the relation ship between weight and measured surface area of fresh tubers and the obtained equations were as follows:

$\mathbf{S}_{mea} = 48.30 + 0.761\ \mathbf{W}$ $\quad\quad$ $\mathbf{R}^2 = 0.94$ for Diamont variety.

$\mathbf{S}_{mea} = 59.06 + 0.657\ \mathbf{W}$ $\quad\quad$ $\mathbf{R}^2 = 0.95$ for Santana variety.

Where:

$\mathbf{S}_{mea}$ = fresh potato tubers surface area (cm^2),

$\mathbf{W}$ = weight of individual tubers (g),

Appositive relationship was found by the previous equations.

Significant differences were appeared with respect to the measured and calculated surface area. In the same time, Santana variety tubers had the maximum differences between the two parameters in the average values.

Repose angle

It is clear from data in Table (2) that the mean values of repose angle of tubers were $31^{\circ}\ 33'$ and $34^{\circ}\ 50'$ for Diamont and Santana varieties. In the same time, non significant differences were found between the two varieties concerning repose angle.

Static coefficient of friction

Data of coefficient of static friction of potato tubers showed that the coefficient of static friction of potato tubers was the highest on steel followed by wood, and then rubber surfaces. It increases with increasing storage time against all surfaces in the two storage systems. It may be due to the changes happened in the tuber surface during storage (lash in potato surface). Generally, as it can be observed from the following regression equations a positive relationship was happened between the static coefficient of friction and storage time.

a-Rubber surface:

Santana variety	$\mu_{Nawalla} = 0.0014\ ST + 0.459$	$R^2 = 0.99$
	$\mu_{Cold} = 0.0009\ ST + 0.461$	$R^2 = 0.97$
Diamont varirty	$\mu_{Nawalla} = 0.0019\ ST + 0.471$	$R^2 = 0.99$
	$\mu_{Cold} = 0.0015\ ST + 0.467$	$R^2 = 0.99$

b-Steel surface:

Santana variety	$\mu_{Nawalla} = 0.0009\ ST + 0.547$	$R^2 = 0.99$
	$\mu_{Cold} = 0.0005\ ST + 0.545$	$R^2 = 0.97$
Diamont varirty	$\mu_{Nawalla} = 0.0011\ ST + 0.607$	$R^2 = 0.97$
	$\mu_{Cold} = 0.0007\ ST + 0.607$	$R^2 = 0.94$

c-Wood surface:

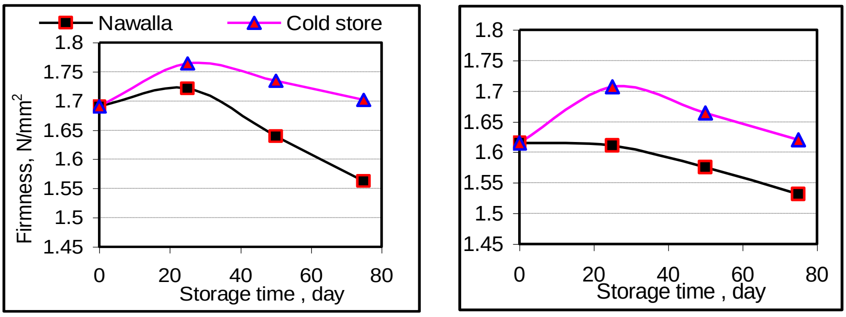
Santana variety	$\mu_{Nawalla} = 0.001\ ST + 0.488$	$R^2 = 0.88$
	$\mu_{Cold} = 0.0009\ ST + 0.477$	$R^2 = 0.99$
Diamont varirty	$\mu_{Nawalla} = 0.0012\ ST + 0.495$	$R^2 = 0.95$
	$\mu_{Cold} = 0.0008\ ST + 0.487$	$R^2 = 0.99$

Where: $\mu_{cold;Nawalla}$ is coefficient of static friction of potato tubers in Cold and Nawalla storage systems;

ST : is the storage time, days.

Firmness (N/mm^2) and Penetration (N)

. The resulted statistical analysis of the investigated data are presented in Table (3) and Table (4).It is clear from the tables that the results of both firmness and penetration force tests had the same behavior on potato tubers. It is observed that both firmness and penetration force increase slightly up to the first 25 days under the storage conditions in Cold (4C; 90% R.H.) and traditional, (16$\pm$ 3C; 84% R.H.) storage systems. It may be because of the high elasticity of the tubers in this period due to the higher percentage of water loss. Mean while, both of the two parameters decrease with storage time. Concerning the potato variety, it was noticed that the minimum firmness N/mm^2 and penetration force N values recorded when potatoes were storage in Nawalla storage system. These results of firmness and penetration force of tubers affected by storage time are graphically presented in figures (6) and (7).



a-Diamont variety **b-Santana variety**

Figure (6): Relationship between firmness (N/mm^2) and storage time (days) at two storage systems for potato tubers varieties

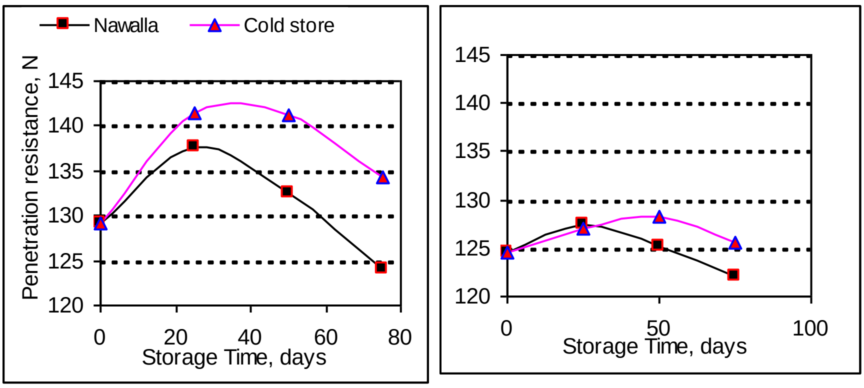


Figure (7): Relationship between penetration resistance (N) and storage time (days) at two storage systems for potato tubers varieties

In the same time the following quadratic regression equations were produced for the experimental data and explained the mentioned behavior before.

$$\mathbf{Y = a\,X^2 + b\,X + c}$$

Where:

Y: is firmness, (F_{cold} $F_{Nawalla}$), N/mm^2, Penetration force (Pr_{cold} $Pr_{Nawalla}$), N

X : is the storage time, (*ST*), days; and a, b, c : are constants,

The values of a, b, c varied according to the investigated varieties .

Diamont variety	:	$F_{cold} = -0.00006\,ST^2 + 0.0052\,ST + 1.6513$	$R^2 = 0.85$
	:	$F_{Nawalla} = -0.00006\,ST^2 + 0.0033\,ST + 1.6518$	$R^2 = 0.89$
Santana variety	:	$F_{cold} = -0.00007\,ST^2 + 0.0058\,ST + 1.58$	$R^2 = 0.91$
	:	$F_{Nawalla} = -0.00003\,ST^2 + 0.0018\,ST + 1.578$	$R^2 = 0.79$

Diamont variety	:	$Pr_{cold} = -0.0088\,ST^2 + 0.75\,ST + 127.05$	$R^2 = 0.93$
	:	$Pr_{Nawalla} = -0.0078\,ST^2 + 0.53\,ST + 127.17$	$R^2 = 0.84$
Santana variety	:	$Pr_{cold} = -0.0024\,ST^2 + 0.2\,ST + 123.67$	$R^2 = 0.92$
	:	$Pr_{Nawalla} = -0.0028\,ST^2 + 0.18\,ST + 123.84$	$R^2 = 0.84$

Table (3): Statistical index of firmness (N/mm^2) for the investigated varieties for fresh, cured and under storage systems (Nawalla and Cold store) for potato tubers:

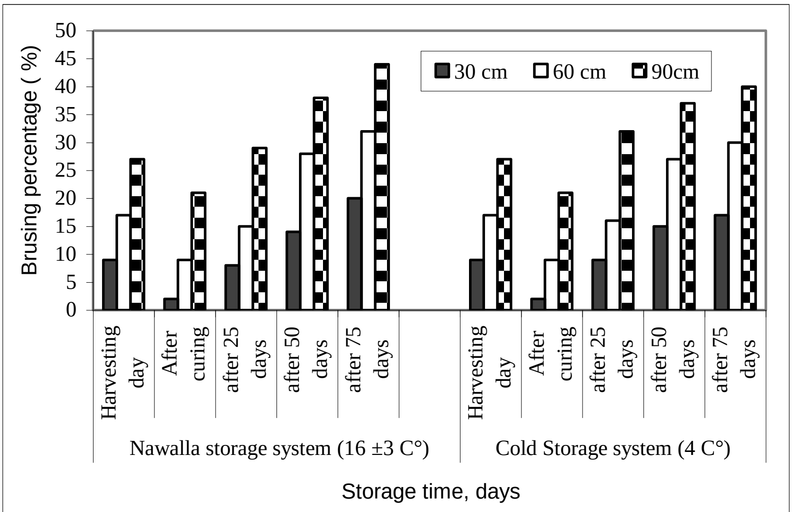
Store system	Storage time, day	Variety	Average $\bar{X}$	Range, Max - Min	S.D. (δn-1)	C.V. %
Natural	**Harvesting day**	**Diamont**	**1.605**	**1.896 – 1.133**	**0.1605**	**9.99**
		Santana	**1.536**	**1.817 – 1.131**	**0.1339**	**8.71**
	After curing period	**Diamont**	**1.69**	**2.022 – 1.376**	**0.1878**	**11.11**
		Santana	**1.615**	**1.904 – 1.238**	**0.1554**	**9.62**
Cold store	**After 25 days**	**Diamont**	**1.764**	**2.079 – 1.417**	**0.1464**	**8.29**
		Santana	**1.707**	**1.942 – 1.374**	**0.1316**	**7.70**
	After 50 days	**Diamont**	**1.734**	**2.048 – 1.353**	**0.1658**	**9.55**
		Santana	**1.664**	**1.906 – 1.318**	**0.1789**	**10.75**
	After 75 days	**Diamont**	**1.702**	**1.955 – 1.213**	**0.1929**	**11.33**
		Santana	**1.620**	**1.825 – 1.246**	**0.2053**	**12.66**
Nawalla store	**After 25 days**	**Diamont**	**1.721**	**2.036 – 1.552**	**0.114**	**6.64**
		Santana	**1.611**	**1.992 – 1.279**	**0.146**	**9.07**
	After 50 days	**Diamont**	**1.639**	**1.976 – 1.484**	**0.135**	**8.24**
		Santana	**1.574**	**1.903 – 1.268**	**0.158**	**10.06**
	After 75 days	**Diamont**	**1.562**	**1.93 – 1.389**	**0.161**	**10.34**
		Santana	**1.53**	**1.841 – 1.186**	**0.182**	**11.88**

Table (4): Statistical index of penetration resistance (N) for the investigated potato tubers varieties under storage systems (Nawalla and cold stores):

Store system	Storage time, day	Variety	Average $\bar{X}$	Range, Max - Min	S.D. (δn-1)	C.V. %
Natural	Harvesting day	**Diamont**	**124.45**	**145.1 – 95.3**	**9.734**	**7.822**
		Santana	**122.89**	**137.4 – 102.6**	**8.588**	**6.988**
	After curing period	**Diamont**	**129.48**	**151 – 103.4**	**10.207**	**7.883**
		Santana	**124.5**	**142.3 – 107.4**	**9.735**	**7.921**
Cold store	After 25 days	**Diamont**	**141.848**	**158.4 – 115.8**	**11.587**	**8.169**
		Santana	**127.103**	**144.3 – 106.6**	**10.265**	**8.076**
	After 50 days	**Diamont**	**141.29**	**169.2 – 111.1**	**14.302**	**10.122**
		Santana	**128.19**	**153.9 – 99.5**	**13.98**	**10.905**
	After 75 days	**Diamont**	**134.25**	**160.1 – 105.4**	**15.95**	**11.882**
		Santana	**125.66**	**143.5 – 97.7**	**14.824**	**11.797**
Nawalla store	After 25 days	**Diamont**	**137.38**	**161.7 – 116**	**9.436**	**6.868**
		Santana	**126**	**152.6 – 104.8**	**10.373**	**8.232**
	After 50 days	**Diamont**	**132.44**	**155.5 – 111.6**	**10.975**	**8.287**
		Santana	**125.118**	**196.1 – 99.9**	**13.945**	**11.145**
	After 75 days	**Diamont**	**124.11**	**146.5 – 101.4**	**11.875**	**9.568**
		Santana	**122.1**	**187.6 – 92.6**	**14.895**	**12.199**

Impact height

The percentage of bruising tubers (damaged due to impact height) for fresh; cured and under storage conditions are presented in figure (8). It is cleared that the least damaged tubers due to free falling were obtained from a height of 30cm when handled after they have been cured (15 days). The figure also shows that the percentage of fresh damaged tubers increases due to increasing the height of free falling. Similarly, the experimented tubers showed an increment in the percent damaged tubers with storage time for the two varieties. This can be explained by the fact that during storage time some physical and chemical factors occurred in tubers as changing some carbohydrate materials into sugar material and potato shrinkage due to the high water loss percentage particularly after harvesting.



a-Diamont variety

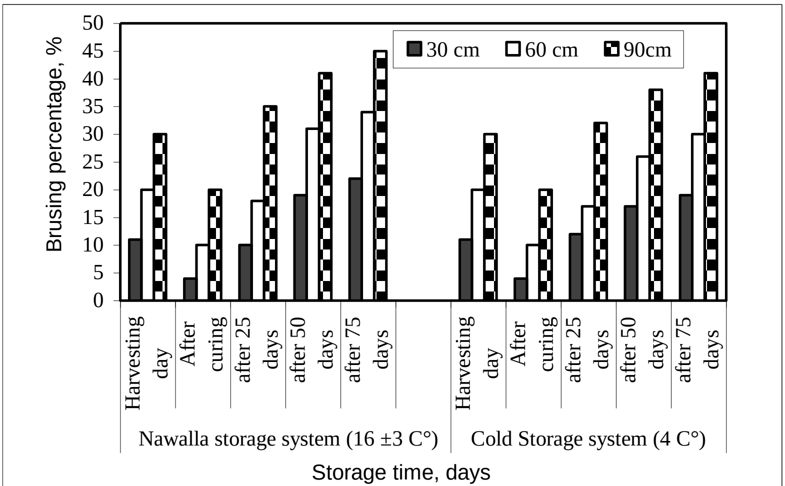


Figure (8): Bruising percentage of potato tubers due to impact height for fresh tubers; after 15 days curing period and during the storage of tubers in Nawalla and Cold storage systems for a-Diamont and b-Santana varieties.

Multiple linear regression equations were obtained from the analyzed data which confirmed that both the falling height (cm) and storage time (days) were directly proportional with the percent of bruised tubers due to impact height as follows:

a-Diamont variety:

Nawalla: $B.P.\ \% = 0.29\ ST + 0.37\ H - 11.33$ R^2=0.98

Cold store: $B.P.\ \% = 0.25\ ST + 0.36\ H - 9.85$ R^2=0.96

b-Santana variety:

Nawalla: $B.P.\ \% = 0.3\ ST + 0.36\ H - 8.87$ R^2=0.96

Cold store: $B.P.\ \% = 0.25\ ST + 0.33\ H - 6.98$ R^2=0.96

Where:

B.P % is bruise percentage - *ST* is storage time, days;

H is impact height, cm.

Chemical properties

a) Moisture content:

Table (5): Statistical index of moisture content, (*M.C*, %) for the investigated varieties

Store system	Storage time, day	Variety	Average $\bar{X}$	Range, Max - Min	S.D. (δn-1)	C.V. %
Natural	Harvesting day	Diamont	81.06	86.33 – 78.68	2.26	2.78
		Santana	83.35	87.78 – 79.84	1.81	2.17
	After curing period	Diamont	80.11	84.84 – 77.35	2.48	3.09
		Santana	82.25	85.97 – 78.77	2.85	3.46
Cold store	After 25 days from storage	Diamont	79.63	82.85 – 75.19	2.67	3.28
		Santana	81.23	84.61 – 77.27	2.94	3.79
	After 50 days from storage	Diamont	77.49	81.35 – 73.21	3.24	4.18
		Santana	79.55	82.18 – 74.07	3.59	4.7
	After 75 days from storage	Diamont	76.35	79.47 – 72.57	2.78	3.53
		Santana	78.64	81.47 – 73.84	2.57	3.26
Naw alla store	After 25 days from storage	Diamont	78.20	81.81 – 77.14	1.09	1.39
		Santana	80.82	83.33 – 78.42	2.04	2.52
	After 50 days from storage	Diamont	74.55	80.84 – 72.75	1.89	2.41
		Santana	78.20	81.64 – 73.14	2.15	2.94
	After 75 days from storage	Diamont	73.13	77.25 – 70.64	2.97	3.84
		Santana	77.26	80.06 – 71.25	2.75	3.55

Data in Table (5) represents changes in moisture content (% wet basis) for fresh; cured and during storing potato varieties in the two storage systems. It is clear from data in the Table and the following linear regression equations also that storage time (days) was inversely proportional with tubers moisture content.

Diamont variety	:	$M.C_{cold} = -0.05\,ST + 80.41$	$R^2 = 0.95$
	:	$M.C_{Nawalla} = -0.1\,ST + 80.19$	$R^2 = 0.97$
Santana variety	:	$M.C_{cold} = -0.05\,ST + 82.29$	$R^2 = 0.99$
	:	$M.C_{Nawalla} = -0.07\,ST + 82.27$	$R^2 = 0.97$

Where:

$M.C_{cold}$, $M.C_{Nawalla}$ are moisture content, % wet basis; ST is the storage time, days.

It is obvious from the drawn equations also that the smaller moisture losses were happened when potato tubers were stored in the cold storage systems.

b) Sugar concentration:

The analyzed results of sugar concentration (S.C, Prix) are presented in figure (9).

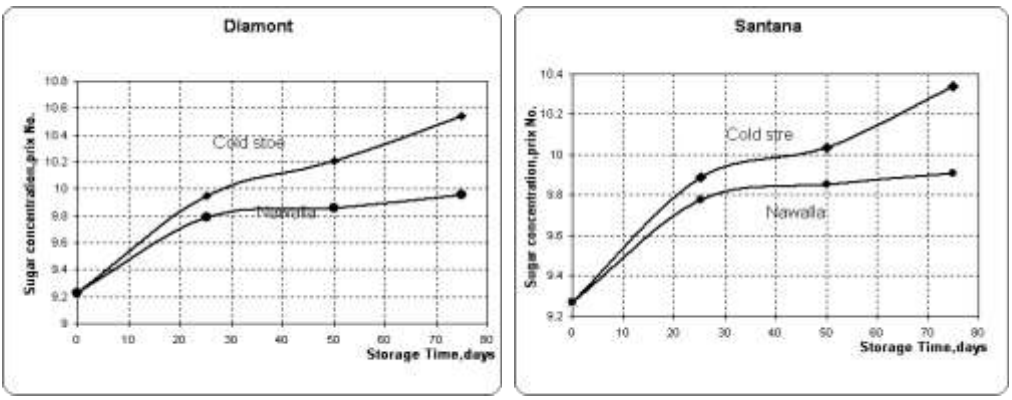


Figure (9): Changing in sugar content of potato tubers during storage time at different types of stores for Diamont and Santana varieties.

The plotted data in the figure show that sugar concentration increases with increasing storage period. The values of sugar concentration were higher in tubers stored in Cold storage system. This may be due to the lower temperature within this system, so a higher breathing rates associated with biological operations for tubers were the main effects for increasing of sugar concentrated percentage in the traditional system also The following regression equations confirm the positive relationship between sugar concentration and storage time in the storage systems used in this investigation.

Diamont variety	$S.C_{cold} = 0.037\ ST + 8.69$	$R^2 = 0.95$
	$S.C_{Nawalla} = 0.022\ ST + 8.93$	$R^2 = 0.88$
Santana variety	$S.C_{cold} = 0.033\ ST + 8.7$	$R^2 = 0.96$
	$S.C_{Nawalla} = 0.023\ ST + 8.87$	$R^2 = 0.88$

CONCLUSION

1-Santana tubers variety were higher in both average and range values of the main dimensions when compared with Diamont variety.

2-Shape of both varieties was characterized between spherical and oval. Storage time slightly affected tubers shape index.

3-The weight of tubers had a positive relationship with the main dimensions and a negative relation with storage time.

4-The actual volume of tubers exerted slight decrement with storage time which was higher when tubers were stored in Nawalla.

5-A positive relationship was found between static coefficient of friction and storage time.

6-Both firmness and penetration force of potato tubers with skin increased slightly up to the end of the first 25 days of the storage period and then decreased with storage time The minimum values of the two parameters were observed when tubers stored in the traditional system.

7-The values of sugar concentration recorded were higher in tubers stored in cold system than the traditional one.

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الملخص العربي

الخصائص الطبيعية و الخواص الكيميائية لدرنات البطاطس تحت انظمة مختلفة للتخزين.

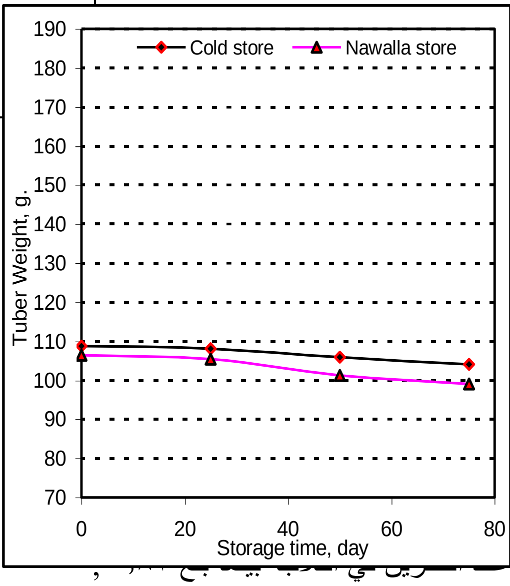
د. جمال رشاد جامع* د. محمد عبد الفتاح عبد المقصود* م.عبد الجواد محمد عبد الجواد**

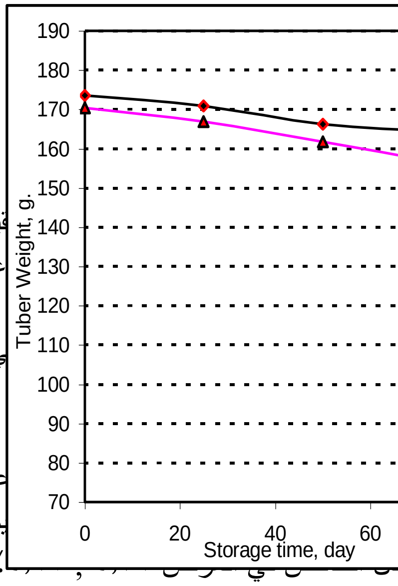
تم في هذا البحث دراسة أهم الخصائص الطبيعية و الخواص الكيميائية لدرنات البطاطس في المراحل الآتية: ما بعد الحصاد مباشرة (طازجة) – بعد معالجتها بالتجفيف و كذلك خلال فترات تخزين مناسبة تحت نظامين مختلفين للتخزين بغرض التعرف على سلوك هذه الخصائص الهامة خلال هذه المراحل مما يفيد في عمليات التداول و التخزين و غيرها.

عناصر البحث

- تمت الدراسة على صنفين من البطاطس دايمونت وسنتانا.
- تم قياس الخصائص الطبيعية لدرنات الصنفين في الثلاث مراحل الآتية : بعد الحصاد مباشرة – بعد فترة ١٥ يوماً (للعلاج التجفيفي و التآم الخدوش الطفيفة) – أثناء التخزين لفترة ٧٥ يوماً مقسمة كل ٢٥ يوم تحت نظامين محليين للتخزين بغرض تقدير هذه الخصائص و تحليل هذه القياسات إحصائيا.
- تم التخزين في الثلاجة العادية على4 درجة مئوية و رطوبة نسبية ٩٠٪ - و كذلك في الثلاجة البدائية (النوالة) على درجة ٣± ١٦ درجة مئوية, رطوبة نسبية ٨٥٪.

* أستاذ مساعد الهندسة الزراعية قسم الهندسة الزراعية - كلية الزراعة – جامعة المنوفية.
** مهندس بمعهد بحوث الهندسة الزراعية – القاهرة.





- اشتملت
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– الوز
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- و اشتما
المحتوى
و كانت النتا
١- بلغ معدا
٪٩,٧
بينما بلغ معد
٤,٧٤٪ عند التخزين في النوالة وذلك في صنفي دايمونت و سنتانا على التوالي.

٢- صنفت أشكال درنات البطاطس لكلا الصنفين على أنها بين الكروية و الاهليليجية.

٣- لم يعتبر الاختلاف في كل من الحجم المحسوب و الحجم المقاس للدرنات معنوياً

٤- أظهرت نتائج الانحدار الخطي علاقة ايجابية بين المساحة السطحية المقاسة لدرنات البطاطس وزن الدرنة وهي علاقة منطقية.

٥- بالنسبة إلى كل من صلابة الدرنات والمقاومة للاختراق في وجود القشرة فقد أخذتا ها تين الخاصيتين اتجاه العلاقة التربيعية حيث ازدادت الخاصيتين في الفترة الأولى و تقريباً حتى ٢٥ يوماً الأولى بعدها بدأنا في النقصان و حتى نهاية فترة التخزين في كلا النظامين.

٦- كان سقوط الدرنات الحر من الارتفاع ٣٠سم وخاصة بعد فترة العلاج التجفيفي يحدث أقل نسبة في الدرنات التالفة نتيجة السقوط عنه عند السقوط من الارتفاعين٦٠سم أو ٩٠سم وبصفة عامة كانت هناك علاقة طردية ايجابية بين نسبة الدرنات التالفة مع فترة التخزين وبين زيادة ارتفاع السقوط الحر.

١١- ازدادت نسبة تركيز السكر في درنات البطاطس التي تم تخزينها في الثلاجة عنها في النواله وقد يرجع ذلك للعلاقة الطردية بين انخفاض الحرارة و زيادة تركيز السكريات في البطاطس.

أما نسبة تركيز السكر للدرنات بعد الحصاد فقد تراوحت بين ٨,٤ إلى ١٠وبين ٨ إلى ١٠ بريكس لكل من صنفي دايمونت وسنتانا على الترتيب,وذلك بالرغم من العلاقة الطردية التي أكدتها علاقة الانحدار الخطي بين فترة التخزين ونسبة تركيز السكريات.