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HARVEST TIME AND SUGAR COMPOSITION OF EARLY AND LATE CULTIVATED STAPLE-TYPE SWEET POTATO (*IPOMOEA BATATAS (L) LAM*) CULTIVARS ON THE JOS PLATEAU, NIGERIA.

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ABSTRACT

Sweet potato (*Ipomoea batatas (L) Lam)* is a Staple – type food source on the Jos Plateau. A study was carried out to assay for its carbohydrate and soluble sugars at different harvest times. The improved varieties CIP4400168, Ex-Igbariam, Tanzania, TIS 8164 and TIS 87/0087 and local landraces, Jandankali I, Jandankali II, Jandankali III local varieties were collected from farmers on the Jos Plateau. These were planted within Jos, harvested after 4 and 6 months, processed into chips of 1 x 1 x 6mm dimension, dried in Air oven drier, milled and sieved to fine flours. One gram (1.0g) of the flour was dissolved in 50ml of distilled water, shaken in 250ml flask to extract its constituents, tested for carbohydrate and soluble sugars qualitatively and quantitatively for glucose, fructose, maltose and sucrose. All the samples tested positive for carbohydrate and reducing sugars. There were significant differences ($P \leq 0.05$) in the glucose, fructose, maltose and sucrose content of the samples for 4 and 6 months harvests. The glucose content ranged between 1.83 and 3.71 g/100g dry weight bases (dwb); fructose, 0.33 – 5.03 g/100g dwb; maltose, 0.09 – 0.98 g/100g dwb and Sucrose, 11.55 - 31.14 (g/100g. Glucose content of both samples was higher than fructose and maltose but lower, than sucrose, fructose content was lower than sucrose but higher than maltose and sucrose in both harvests exceeded that of glucose, fructose, and maltose. The maturity of the root tubers was found to influence their sugar content which can serve as a guide in proving information for harvest timing and fresh produce quality of specific target cultivars, with the view to match with specific formulations.

Keywords: *Harvest time, Cultivar, Glucose, Fructose, Maltose and Sucrose*

INTRODUCTION

Sweet potato (*Ipomoea batatas (L) Lam*) is highly produced within the 9 Local Government Areas on the Jos Plateau. The root tuber is highly digestible, consisting of starch, proteins of high biological value; a variety of minerals and trace elements, rich in carotene, ascorbic acid, vitamins but low in lipids; contains several bioactive compounds with anti-oxidants, radical scavenging and other therapeutic and immunity boosting properties (Ezekiel *et al.,* 2010; Tung-Chang *et al.,* 2013; Evelyn *et al.,* 2014; Adda, 2019). The crop is genetically diverse, highly under exploited with persistent low utilization for decades despite its high status as a staple food on the Jos Plateau.

The roots become moister and sweeter in taste after harvest, high in moisture content ranging between 62.58 – 64.34, dry matter is low; carbohydrate consists mainly of starch (60 – 70%) which varies with the cultivar's maturity, storage time and sugars; less pectin, hemicellulose and cellulose (Liu *et al.,* 2009; Rose and Hilda, 2011; Adda, 2019). Sugar in the tuber is a fundamental aspect of its eating quality. Different ethnic tribes on the Jos Plateau have different preference for the sugar content in the tubers which are grouped into those that can be produced into staples, supplemental staple and luxury types based on sugar and dry matter. Some of the tribes preferred types that are non-sweet and are grouped as staple carbohydrate energy source while sweeter tubers are processed into local sweeteners and related foods. Sweetness in the tuber is due to the presence of endogenous sugars: sucrose, glucose, fructose at harvest and maltose formed through starch hydrolysis by amylase enzyme during storage or through heat treatment (Onwuka, 2005; Evelyn *et al.,* 2014).

The variability in total sugars between samples ranged between 0.38% - 5.64% fresh weights bases (Picha 1986; Ukom *et al.,* 2009). The sugars at the same concentration are known to have different perceivable sweetness levels, glucose is twice as sweet as maltose, sucrose is three times sweeter than maltose and fructose is five times as sweet as maltose (Evelyn *et al.,* 2014). Sugars are known to affect the processing behaviour of starchy foods. Gelatinization temperature, degree of gelatinization and retrogradation are all influenced in the tuber due to the content of the sugars. The presence of high sugar content may also affect appearance of some heat-processed products by causing excessive darkening due to enzymatic browning. Most methods used in the analyses of the sugars indicated that sucrose is in higher concentration than the other sugars (Lewthwaite *et al.,* 2010). Raffinose, stachyose and verbascose were the other oligosaccharides assayed in the tubers (Zhang, *et al.,* 2002; Aina *et al.,*2009).

On the Jos Plateau, the tubers compete favourably with cassava, cocoyam, taro and yam in caloric content (Sila *et al.,* 2017). Production is high with minimal processing and utility is threefold: human food, animal feed and alcohol and starch (FAO, 2013). The tubers from different home steads are briefly stored and sold at the rural markets then transported to the urban markets of Jos where they get glutted due to poor patronage during retailing. The tubers under marketing conditions have a shelf-life of only 1- 2 weeks

The shelf life of the tuber is very short due to high percentage moisture content, high nutrient content, handling faults, the activities of biodeteriogens, sprouting and hardening (Ahmed *et al.,* 2010). These factors result in huge economic losses incurred by the farmers and traders of the commodity. The only solution to these problems is to process the fresh tubers into higher–value products with extensive shelf-life that will be available all year round. Processing will also stem the glutting of the tubers which causes a sharp drop in its price during the production season.

Sweet potato root tuber has been identified as a suitable raw material that can be harnessed for both domestic and industrial purpose. If sugar contents and composition of the cultivars are significantly affected by harvest age then timing the harvest appropriately will be an effective means of controlling the eating quality and processing characteristics. This will assist in harvesting desired sugar levels for specific end-uses; low sugar for staple food uses and high sugars for the production of sweeteners and related foods. The tubers are sliced into chips, sun-dry, grand, seize into refined flour and put into different uses. The fresh tubers are crushed and the extract is used as a sweetener. Many other forms of usage of the tubers with other crops into different foods abound amongst the tribes. The determination of the sugar composition of the cultivars will aid in the formulation of baby food, custard, biscuits, bread and chinchin (a local product).

Therefore the objective of this research is to assay for the sugar contents of both the high breeds and popular local varieties at different harvest times to determine the types and kinds of products they could be formulated into vis-a-vis their sugar composition. This will be an added value of the tuber to food sufficiency and security on the Jos Plateau of Nigeria.

MATERIALS AND METHODS

A plot of land was carved out in a private farm at Rayfield in Jos, 9.2^0 North Latitude, 8.9^0 East Longitude and 1208 meters elevation above sea level, with a cool temperature of 34.5^0 – 13^0C (GPS of Jos and environs, Aug 2019). The weather encourages the production of temperate and tropical crops like sweet potato. The soil is adequately drained and receives rays of sunshine in the wet and dry seasons of the year.

Samples of five improved cultivars: CIP4400168, Ex-Igbariam, Tanzania, TIS 8164 and TIS 87/0087 and three local cultivars (Land-racers): Jandankali I, Jandankali II, Jandankali III were processed into chips of 1 x 1 x 6mm dimension, dried in Air oven drier at 60^0C for 72h, milled and sieved through 250µm mesh size sieve to obtain fine flours (Evelyn *et al,* (2014) One gram (1.0g) of each flour was weighed out, dissolved in 50ml of distilled water in 250ml flask; put in a mechanical shaker for 6 hours to extract the constituents; different quantities of the supernatant were collected and tested for carbohydrate and reducing sugars qualitatively and quantitatively for glucose, fructose, maltose and sucrose.

Each experiment was replicated 3 times and the data obtained were statistically analysed using Two-Way Analysis of Variance (ANOVA), computed with Statistical Package for Social Science (SPSS) version 8. Duncan's New Multiple Range Test (DMRT) was specifically used to separate treatment means.

Test for Carbohydrate (Anthrone qualitative method)

To about 5ml of Anthrone reagent in different labelled tubes was added 5 drops of each of the supernatant and then allowed to stand for 10mins. Bluish–green colouration is indicative of carbohydrate presence and the intensity of each is depended on its concentration.

Test for Reducing Sugars (Benedict's qualitative reagent method)

To about 5ml of Benedict's reagent in labelled tubes was added 5 drops of each of the supernatant and then put in boiling water in 500ml beaker on a hot plate for 10 min. An orange precipitate or brick red colour was indicative of reducing sugars presence and the intensity of each depended on its concentration. The reaction is represented as follow:

Reducing Sugar + 2 C $\rightarrow$ Oxidized Sugar + 2 Cu+

2Cu+ 2OH 2CuOH $\rightarrow$ Cu_2 + H_2O $\rightarrow$ Yellow/Red

Quantitative Determination of Glucose (O'Tuluidine method)

Three (3) test tubes were arranged in a test-tube rack, 0.1ml of each supernatant was pipetted into the first and second tubes, labelled "Test" and "Standard" respectively; 0.1ml of distilled water was pipetted into the third tube, labelled "Blank"; 5.00ml of the reagent was pipetted into them, plugged with cotton wool, shaken thoroughly, boiled in 500ml beaker on a hot plate for 10 min, allowed to cool; blue-green colour complex formed was indicative of glucose. The sample and standard were read against the blank in cuvette of colorimeter at 625nm; absorbance values obtained were used to calculate glucose concentration of the samples by applying the Beer-Lambert's formula:

$$\frac{OD_{test}}{OD_{std}} \times \frac{\text{concentration}}{\text{of std used}} \times \frac{100}{\text{Vol. of sample used}}$$

Where: ODtest = Absorbance of sample's glucose

ODstd = Absorbance of standard's glucose

Each experiment was replicated 3 times and the values were analysed as stated above.

Quantitative Determination of Fructose (Seliwanoff's reagent method)

Three (3) test tubes were arranged in a test tube rack, 0.01ml of the supernatant was pipetted into the first and second tubes, 0.01ml distilled water into the third test tube; 5.00ml of the reagent was pipetted into the 3 tubes, plugged with cotton wool and processed as descried above. The sample and standard were then read against the blank in cuvette of colorimeter at 470nm, absorbance values obtained were used to calculate the concentration of fructose in the samples by applying the Beer-Lambert's formular:

$$\frac{OD_{test}}{OD_{std}} \times \frac{\text{concentration}}{\text{of std used}} \times \frac{100}{\text{Vol. of sample used}}$$

Where: OD_{test} = Absorbance of Sample's fructose

OD_{std} = Absorbance of Standard's fructose

The experiment was replicated 3 times and the values were analysed as stated above.

Quantitative Determination of Maltose (O'Tuluidine method)

Maltose is a reducing disaccharide, made up of 2 glucose units as shown below in a revisable reaction.

$$\text{MALTOSE} \xrightleftharpoons{\text{HYDROLYSIS}} \text{GLUCOSE + GLUCOSE}$$

Five (5) drops of 6M HCL was added to 0.01ml of each of the supernatant in tubes, boiled for 10 min, blue–green colour complex formed was read colorimetrically at 625nm. Glucose concentration was obtained by applying the Beer-Lambert's formular and the final value was multiplied by factor 2 to determine the maltose concentration of each sample. The experiment was replicated 3 times and the values were analysed as stated above.

Quantitative Determination of Sucrose (Seliwanoff's reagent)

Sucrose is a non-reducing disaccharide. It is made up of Glucose and Fructose units as shown below in a revisable reaction.

$$\text{SUCROSE} \xrightleftharpoons{\text{HYDROLYSIS}} \text{GLUCOSE + FRUCTOSE}$$

The samples were first hydrolysed by adding 5 drops of 6M HCL to 0.01ml of each of the supernatant in tubes. The mixture was boiled for 10 mins thereafter, Seliwanoff's reagent was used to assay for the fructose level; red colour complex formed was read colorimetrically at 470nm. Fructose concentration of each sample was obtained by applying the Beer-Lambert's formular for fructose determination; the values were added to the calculated Glucose values determined for maltose. The experiment was replicated 3 times and the values were analysed as stated above.

RESULTS AND DISCUSSION

All the samples tested positive for carbohydrate and reducing sugars; colour intensity varied with concentration. The qualitative test indicated that the reducing sugar concentration of Ex-Igbariam, Jan 11, Tanzania, TIS 8164 and TIS 87/0087 were high. The reducing sugar concentration was higher in all the tubers harvested after 4 months than those at 6 months harvest (Table 1). The analyses of the sugar content of the samples on dry weight bases (dwb) are presented in Table 2 and the sugars assayed included:

Glucose (g/100g dry weight basis: dwb)
There were significant differences ($P \leq 0.01$) in the glucose content of the flours at both harvests of 4 and 6 months. The values assayed in the flours ranged between 1.83 and 4.09 (g/100g dwb) for CIP 4400168 harvested after 6 months and Jan 1 and TIS 87/0087 harvested after 4 months respectively (Table 2). Glucose values were high 3.71 (g/100g dwb) in Ex-Igbariam and Jan 1 harvested after 4 months and 3.41 (g/100g dwb) in TIS 8164 harvested after 6 months. The glucose values for the 4 months harvest were much higher than those harvested after 6 months.

Fructose (g/100g dry weight basis: dwb)
The fructose content of the flours of the samples harvested after 4 and 6 months were significantly different ($P \leq 0.05$).

Irrespective of the low fructose content of both flours, variation was more in those of the 6 months harvest and absent in Tanzania samples. The fructose values of the flours for the 4 months harvest samples were higher than those of the 6 months harvest. Fructose values of the flours ranged between 0.33 – 5.03 (g/100g dwb) for CIP 4400168 harvested after 6 months and Ex-Igbariam harvested after 4 months respectively (Table 2).

Maltose (g/100g dry weight basis: dwb)
The maltose content of both flours was very low but differed significantly ($P \leq 0.05$); variation was more in the samples harvested after 6 months. The maltose values assayed in the flours of the samples harvested after 4 months were higher than those harvested after 6 months and ranged between 0.09 – 0.98 (g/100g dwb) for TIS 8167 harvested after 6 months and Ex-Igbariam harvested after 4 months respectively (Table 2)

Sucrose (g/100g dry weight basis: dwb)
Sucrose was in high concentration in the flours assayed from both samples and the values differed significantly ($P \leq 0.05$). The values of the flours of the samples harvested after 4 months were much higher than those harvested after 6 months and ranged between 11.55 - 31.14 (g/100g dwb) for CIP 4400168 harvested after 6 months and Ex-Igbariam harvested after 4 months respectively (Table 2). All the flours assayed had high concentration of sucrose except those of CIP 4400168 with values below 23.67 (g/100g dwb) the minimum assayed in the samples.

Table 1: Qualitative Determination of Carbohydrate of the Powders by Anthrone Method and Reducing Sugars by Benedict Method.

	Carbohydrate		**Reducing Sugars**	
Cultivar	**4MAP**	**6MAP**	**4MAP**	**6MAP**
CIP 440168	P	P	++	+
Ex-Igbariam	P	P	++++	++
Jan I	P	P	+++	++
Jan II	P	P	++++	+++
Jan III	P	P	+++	++
Tanzania	P	P	++++	++
TIS 8164	P	P	++++	+++
TIS 87/0087	P	P	++++	+++

P = Positive + = Intensity.

Table 2: The Sugar Composition of the Root Tubers Harvested after 4 and 6 Months of Planting

Cultivars	Glucose (g/100g dwb)		Fructose (g/100g dwb)		Maltose (g/100g dwb)		Sucrose(g/100g dwb)	
	4MAP	6MAP	4MAP	6MAP	4MAP	6MAP	4MAP	6MAP
CIP 4400168	2.35g	1.83h	1.23g	0.33g	0.73d	0.50f	21.03h	11.55h
Ex-Igbariam	3.71b	2.86c	5.03a	2.25a	0.98a	0.77a	31.14a	25.41a
Jan I	3.71b	2.55e	1.24f	0.74d	0.83c	0.67b	26.13e	20.62b
Jan II	3.05e	2.46f	1.11h	0.65f	0.60g	0.43g	28.64b	19.33d
Jan III	3.26d	2.66d	1.26d	0.72e	0.89b	0.54d	25.29f	17.73f
Tanzania	2.82f	2.07g	1.55b	NIL	0.71e	0.52e	23.67g	16.25g
TIS 8164	3.41c	2.95b	1.35c	0.85c	0.39h	0.09h	28.10c	19.44c
TIS 87/0087	4.09a	3.08a	1.25e	0.93b	0.70f	0.57c	27.74d	18.53e

*Means with the same letter(s) are not significantly different at 5% level of probability (Duncan's New Multiple Range Test)
Key:4MAP = 4 Months after Planting, 6MAP = 6 Months after Planting.

The soluble sugar concentration of the cultivars at both harvest times was low. However the concentration was higher in all the tubers at 4 months harvest than those at 6 months harvest probably due to conversion of the older tubers sugars into starches hence a reduction in concentration. Wang *et al,* (2006) found that starch and sugars: sucrose glucose and fructose levels correlated with root weight/size during development, with glucose and fructose decreasing gradually and starch contents increasing with the expansion of the tuberous root

The tubers flours differed significantly in glucose, fructose maltose and sucrose assayed at both harvest times. Glucose has been demonstrated in various analyses to be higher or equal to fructose in different varieties. The glucose values were low at all the harvest times and ranged between 1.83 – 4.09 g/100g dwb which differ with the report of Evelyn *et al* (1993) whose values ranged between 0.133 – 0.006 g/100g dwb using high performance liquid chromatography (HPLC) the difference may be attributed to the methods employed in the analyses. Glucose content of most of the cultivars was higher than fructose and maltose but lower, than sucrose. However the fructose value 5.03 (g/100g dwb) of Ex-Igbariam sample harvested after 4 months was higher than all the glucose values of the cultivars harvested at both times. Sweet potato starch can be converted to glucose syrup to increase sweetness in industrial products (Inukai *et al.,* 2002; Kays *et al.,* 2005). The study has identified sweet potato as a good source of glucose, an important raw material in the food industrial, has high production on the Jos Plateau. The root tubers: Ex-Igbariam, Jan 1, Jan 11, Jan111, TIS 8164 and TIS 87/0087 were analysed to be quantitatively rich in the reducing sugar.

Fructose was assayed in both flours of the samples except those of Tanzania at 6 months harvest, agreed with the report of Laurie *et al* (2013) that the sugar could be absent in some cultivars due to environmental conditions. The fructose content of the cultivars was also low but in some cases was equal, higher and lower than glucose but higher than maltose and much lower than sucrose in both the samples. The values of the sugar ranged between 0.33 - 5.03 g/100g dwb higher than the values 0.0665 – 1.6838 g/100g dwb reported by Laurie *et al.* (2013) using HPLC, the difference could also be attributed to the method employed. The values of the reducing sugar of the cultivars at 4 months harvest were higher than those at 6 months harvest. Glucose can further be converted to fructose for increase sweetness in industrial products (Wang *et al.,* 2006)

Maltose was lower than all the other sugars assayed in the cultivars. Vincent (2017) found that the content of maltose in cultivars increased significantly in storage due to starch hydrolysis or when they are subjected to heat treatment. The sugar values assayed for both cultivars did not differ much and ranged between 0.09-0.77 g/100g dwb for cultivars at 6 months harvest to 0.39 - 0.98 g/100g dwb for those at 4 months harvest. Evelyn *et al.* (2014) had shown that the sugar did not differ much in 3, 4 and 5 months harvested cultivars. The values of the sugar in the samples of both cultivars were low as had been identified in raw root tubers by various authors.

The content of sucrose in both harvests assayed exceeded that of glucose, fructose, and maltose (Inukai *et al.,* 2002; Wang *et al.,* 2006; Laurie *et al.,* 2013; Vincent, 2017; Dyah and Fitri, 2020). This agrees with previous reports that cultivars with high sucrose content exhibit low reducing sugar content (glucose and fructose). Mcharo and LaBonte (2007) working with 45 sweet potato clones also confirmed that clones with high sucrose had low levels of glucose and fructose.

The samples sucrose values ranged between 11.55 - 31.14 g/100g dwb for cultivars at 4 and 6 months harvest respectively. This analysis agrees with the report of Evelyn *et al.* (2014) who found sucrose contents to increase in 3 – and - 4 months samples but decrease in those harvested above these periods. Sucrose decrease in the 6 months harvested samples may be due to its utilisation as a carbon source for starch synthesis in reserve tissue since sucrose is made up of glucose and fructose units, Also the 6 months harvested samples decrease in sucrose reflect the uptake of the glucose fraction from sucrose for starch synthesis.

CONCLUSION

All the cultivars but CIP 4400168 was found to be sugary. The sugar values of the cultivar that were at 4 months harvest were much higher than those at 6 months harvest. The maturity of the root tubers was found to significantly influence the sugar content of the cultivars assayed. This finding can serve as a guide in proving information to possibly control the eating quality of the sweet potato root tuber through formation of recommendation for harvest timing and fresh produce quality of specific target cultivars, hoping to march specific formulations with the tubers.

REFERENCES

Adda, B. (2019). Sweet Potato 101: Nutrition, Facts and Health Benefits. Available online at *https/www./healthline.com/nutrition/foods/.*

Ahmed, M., Akter, M.S., and Eun, J.B. (2010). Peeling, drying temperatures and sulphite-treatment effect; physicochemical properties and nutritional quality of sweet potato flour. *Food Chemistry 121:112 – 118*

Aina, A.J., Folade, K.O., Akingbala, J.O. and Titus, P. (2009). Physicochemical properties of twenty-one Caribean sweet potato cultivars. *International Journal of Food Science Technology, 44: 1696 - 1704*

Dyah, T. and Fitri, D.U. (2020). The Effects of Different Processing Technics in Sweet Potato (Ipomoea batatas) Nutritional Content. *https:// doi.org/10.105/33con/202014201007*

Ezekiel, R., Rana, G., Singh, N. and Singh, S. (2010). Physico-chemical pasting properties of starch from stored potato tubers. J*ournal of Food Science Technology, 47: 195 – 201*

Evelyn, A., Esther, O., Sakyi, D., George, S.A., Van-Den, T., Fred, F.S. and Kim, D. (2014). Variability of Sugars in Staple-Type Sweet Potato (Ipomoea batatas) Cultivars. The Effects of Harvest Time and Storage. *International Journal of Food Properties, 17: 2010 - 2014*

FAO (2013). (Food and Agriculture Organisation of the United Nations). The State of Food Insecurity in the World. The multiple dimensions of food security. Rome Italy: FAO

Inukai, Y., Slubayama, H., and Matsubayashi, T. (2002). Growth conditions affecting palability especially sweetness of sweet potato. *Marine and Highland Bioscience Centre Report, 14: 1 – 7.*

Kays, S., Wang, Y. and McLaurin,W.J. (2005). Chemical and geographical assessment of sweetness of the cultivated sweet potato clones of the World. *Journal of American Society for Horticultural Science, 130 (4): 591 - 597*

Laurie, S.M., Faber, M., Calitz, F.G., Moelich,E.I., Muller, N. and Labuschagne, M.T. (2013). The use of sensory attributes, sugar content, instrumental data and consumer acceptability in selection of sweet potato varieties. J*ournal of Science, Food and Agriculture, 93 (7): 1610 - 1619*

Lewthwaite, S.L.; Sutton, K. H.; & Triggs, C.M. (2010). Free sugar composition of sweet potato cultivars after storage. *New Zealand Journal of Crop and Horticultural Science, 25 (1), 33 – 41.*

Liu, Y.; Kirchhof, G.; & Sopade, P.A. (2009). Digestibility of starch and potassium in sweet potato from Papua New Guinea. Proceedings of 15th ISTR Symposium, Peru.

Picha, D. H. (1986). Sugar content of baked sweet potatoes from different cultivars and lengths of storage. *Journal of Food Science, 51: 845 – 846*

Tung-Chang, L., Che-Lung, H., Chin-Feng, C. Ching-Yig, l. and Wayne, C.L. (2013). Studies of sugar composition and starch morphology of baked sweet potatoes (Ipomoea batatas (L) Lam). *Journal of Food Science Technology, 50 (6): 1193 – 1199.*

Ukom, A.N.; Ojimelukwe, P.C. & Okpara, D.A. (2009). Nutrient composition of selected sweet potato (*Ipomoea batatas (L) Lam*) Varieties as Influence by Different Levels of Nitrogen Fertilizer Application. *Pakistan Journal of Nutrition, 8 (11), 1791 – 1795.*

Vincent, L. (2017). Rapid quantitative determination of maltose and total sugars in sweet potato *(Ipomoea batatas (L) Lam)* varieties using HPTLC. *Journal of Food Science Technology 54 (3): 718 - 728*

Wang, S.J., Chen, M.H.,Yeh, K.W., Tsai,C.Y. (2006). Changes in carbohydrate content and gene expression during tuberous root development of sweet potato. *Journal of Plant Biochemistry and Biotechnology 15: 21 - 25*

Zhang, Z., Wheatley, C.C. and Cork, H. (2002). Biochemical changes during storage of sweet potato roots differing in dry matter content. *Postharvest Biology Technology. 24: 317 – 325.*