American Journal of Agricultural and Biological Sciences 7 (2): 232-238, 2012
ISSN 1557-4989

# Relationship between Selected Properties of Starchy Vegetables on Grating and Slicing Production Rate

[1]Lok Chung Yee, [1]M.K. Siti Mazlina, [2]B.T. Hang Tuah
[1]Department of Process and Food Engineering, Faculty of Engineerin,
[2]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering,
Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

**Abstract:** Prediction on the output of grating and slicing of starchy vegetables are important prior to design or develop the particular food plant. The production rate of grating and slicing products could be affected by the properties of starchy vegetables. In this study, two selected properties which hardness and moisture content are studied. Hardness of selected starchy vegetables was measured using a destructive testing method of texture analyzer. A testing machine of the texture analyzer applied a specific blade to shear the vegetables and automatically generate data. The objective of this study was to determine the relationship between starchy vegetables hardness and moisture content which influenced the production rate in grating and slicing products. The selected starchy vegetables used for this study were white potato, sweet potato, tapioca and yam. The maximum hardness was computed and analyzed using the texture analyzer. It was found that the maximum hardness of white potato, yam, sweet potato and tapioca were 6.67, 12.01, 16.98 and 20.08 kg respectively. It was determined that white potato had the highest moisture content among the vegetables, which was 78.14%. In conclusion, the lower value of hardness and higher value of moisture content are significantly correlated to higher production rate of grating and slicing products. Results presented may help the food industry to initially predict the production rate of agricultural products such as food chips and finger products.

**Key words:** Hardness, moisture content, grating, slicing, production rate

## INTRODUCTION

Qualitative evaluation of agricultural products is commonly used to characterize the agricultural product quality such as shape, color, size, texture and taste. Many quality factors of agricultural products are related to products physical properties and non-destructive methods is often used to develop qualitative evaluation (Chen and Sun, 1991). Hardness is one of properties parameter used in evaluating the quality of vegetables.

Hardness is defined as the quality or condition of being hard the Free Dictionary, 2012. Measurement of vegetables hardness property can be performed through destructive or non-destructive testing methods. To study the selected vegetables hardness, the destructive testing method using a texture analyzer with the computer driven testing system was commonly used. Moisture content is defined as the quantity of water in an object which is expressed in percentage by weight of water in mass. Measurement of vegetable moisture content is as similar as measuring hardness, which is can also be used with a destructive testing method with a computer driven testing system known as moisture analyzer. Other important food engineering properties that related to the hardness are solid density which it is defined as the quantity of mass per unit volume (kg/m$^3$) (Barbosa-Canovas *et al*., 2012).

Starchy vegetables are important to supply the energy food needs of many populations in tropical regions (Rubatzky and Yamaguchi, 1997). The contribution of starchy vegetables, although generally is smaller than cereals, is still substantial and significant. In addition, these starchy vegetables are less costly to produce (Rubatzky and Yamaguchi, 1997). Among the starchy vegetables, the white potato is by far the most important contributing to increased production efficiency of starchy vegetables in various processed food industries, especially in the white potato industrial products (Rubatzky and Yamaguchi, 1997).

Types of starchy vegetables highlighted in this research are starchy roots and tubers. Sweet potato and tapioca are the principle starchy vegetable root crops,

**Corresponding Author:** Siti Mazlina M.K., Department of Process and Food Engineering, Faculty of Engineerin,
Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia, Tel: 603 8946 6294

while white potato and yam are the major starchy vegetable tuber crops. Fried potato is famous for its appealing, flavour and aroma (Lisinska and Leszczynski, 1989). The texture of fried potato is mainly depending on the quality of the raw material (Golubowska, 2005). The food materials will undergo physical-chemical changes since frying affects its textural and structural properties (Baik and Mittal, 2003). White potato is one of the selected starchy vegetable studied since potato fries is one of the most popular potato products in many countries. In addition, fried sweet potato chip is also a common snack in Asia and its consumption is increasing (Taiwoa and Baik, 2007). Tapioca and yam are also a part of important crops in tropical countries and are reliable sources of dietary energy. Therefore, in this study, besides white potato, three other starchy vegetables namely sweet potato, tapioca and yam were also tested.

The objective of this research work is to determine the relationship between the hardness and moisture content properties of the starchy vegetables in affecting the production rate of grating and slicing products. The result may assist the food industries to identify and predict the production rate, particularly for grated and sliced outputs.

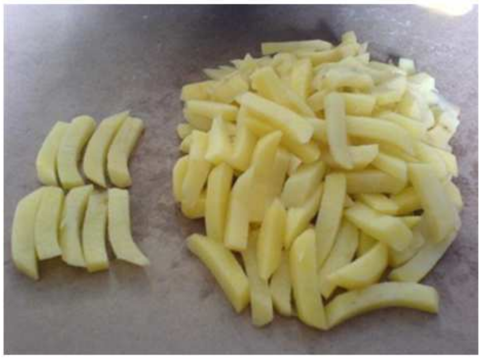
## MATERIALS AND METHODS

**Vegetable raw materials:** The white potato, sweet potato, tapioca and yam were sourced locally and in fresh and fine condition. The vegetables were specifically selected in nearly similar size and shape for the analysis of hard, solid density and moisture content.

**Size of samples:** The size of each sample was determined from 20 samples in term of height (cm), diameter (cm) and mass (g). Table 1 shows the size of the selected starchy vegetables.

**Properties analysis: Hardness:** The destructive testing method using the texture analyzer (TA.XT Plus) was intended for a continuous computer driven testing system to test a range of fruits and vegetables with the purpose of measuring the hardness property. For the hardness analysis, the samples were tested directly to the original size and shape of the samples.

The methodology of this test was simple and effective with the use of built-in computer iteration software. The testing machine used a blade to shear the vegetable and was linked to the computer to generate raw data. A single test running was completed in approximately two min. The testing machine was set for five testing counts. Ten samples of each material were used for the hardness tests.



(a)

(b)

Fig. 1: The sample of grated and sliced outputs. (a) Grated output (potato sample) (b) Sliced output (sweet potato sample)

**Solid density:** Measurement of vegetable solid density was using the non-destructive test method with a computer driven testing system known as gas displacement density analyzer. The use of testing machine (The AccuPyc II 1340-Gas Pycnometer) was made simple and effective with the built-in computer iteration software.

The method used in solid density analysis was similar to hardness analysis, except the tests used non-destructive testing method. The testing machine used helium gas for pressure measurement in an integrated analysis module and produced computer generated raw data for density calculation. All measurements for each vegetable were doing triplicates.

**Moisture content:** The Moisture Analyzer (and MX50) was used to measure the moisture content of the vegetables. The use of this testing machine was made simple and effective with the built-in computer iteration software.

The method used in moisture analysis was similar to the hardness analysis except the time for this test was longer. The testing machine used featured moisture balance, which allowed rapid moisture measurements and produced computer generated raw data. All measurements for each vegetable were doing triplicates.

**Production rate assessment:** The equipment used for grating and slicing was an in-house design meant for this research work. The machine was designed similarly to the ones used in the food processing industry involving in chips and finger food productions. The expected size of the grating output was 10×10 mm (cross sectional area) whereas the sliced output was 2 mm thick. The expected grated and sliced output sizes followed the food industry needs. Somsen *et al.* (2004) did a study on the development of a model to predict the maximum production yield for French fries. However, there is no study that link the grating and slicing production rate with moisture content and hardness. Therefore, the production rate assessment could help the food industries identify and predict the production rate, particularly for grated and sliced outputs, according to the food industry needs. Figure 1 shows the sample of grated and sliced outputs.

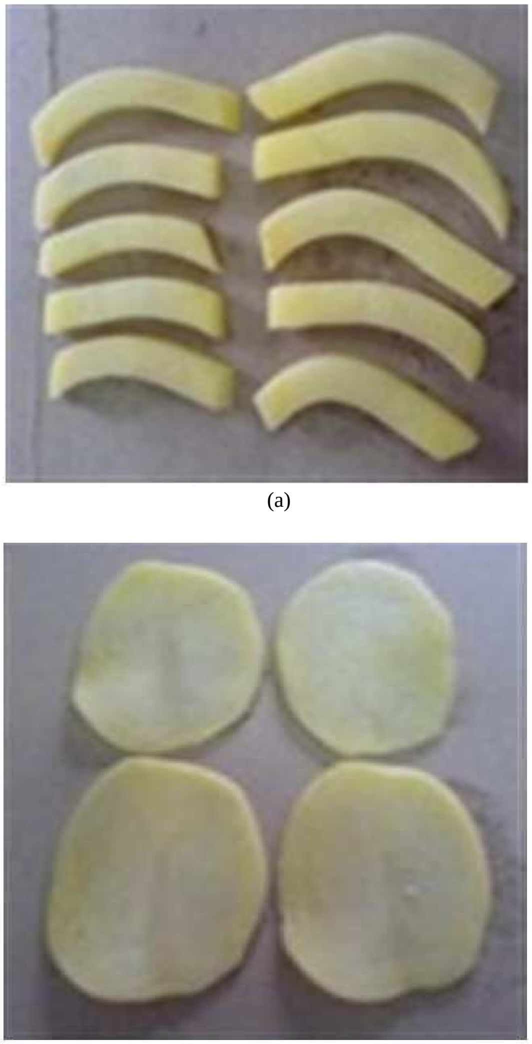
## RESULTS

**Hardness, solid density and moisture content:** Table 2 shows the data results for hardness, solid density and moisture content of the starchy vegetables. The hardness values for the starchy vegetables were in the range of 6-20 kg. Tapioca had the highest hardness value (20.08 kg) and white potato had the lowest hardness value (6.67 kg) among the four vegetables.

**Production rate:** Results for the grating and slicing output at four different speeds (rpm) of the starchy vegetables are shown in Tables 3 and 4. Figure 2 shows the quality observation of potato sample for grated and sliced outputs that was not affected due to speed changes.

The production of grated and sliced tapioca product required more time, compared to white potato (Tables 3 and 4). Figures 3 and 4 show that grating and sliced production rate decreased with decreasing moisture content and increasing hardness value.

Based on the results shown in Tables 3 and 4, the estimated production time for a tonne of grating and slicing products was made. Tables 5 and 6 show estimated production time (hourly) to produce a tonne of grated and sliced products.


(a)

(b)

Fig. 2: Quality observation of potato sample for grated and sliced outputs that was not affected due to speed changes (a) Grated output (potato sample) (b) Sliced output (sweet potato sample)

Table 1: Size of the selected starchy vegetables

| Starchy Vegetable | Height (cm) | Diameter (cm) | Mass (g) |
|---|---|---|---|
| White Potato<br>(*Solanum Tuberosum*) | 7. 15±0.04 | 5.11±0.04 | 60.17±0.05 |
| Sweet Potato<br>*(Ipomoea Batatas)* | 10. 16±0.04 | 4.59±0.04 | 82.10±0.03 |
| Tapioca<br>*(Manihot Escylenta)* | 10. 29±0.03 | 4.12±0.02 | 102.38±0.05 |
| Yam<br>*(Dioscorea)* | 12. 00±0.04 | 10.59±0.04 | 120.37±0.04 |

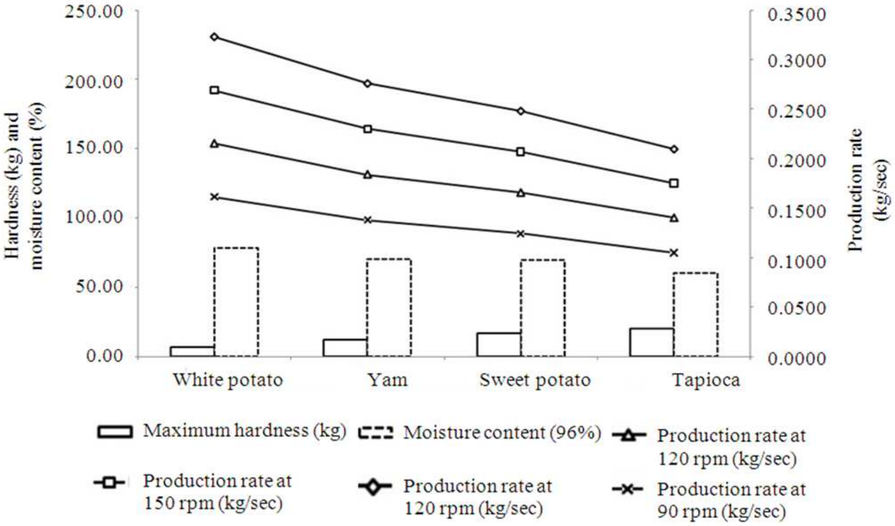


Fig. 3: Relationship of grated production rate to hardness and moisture content for starchy vegetables

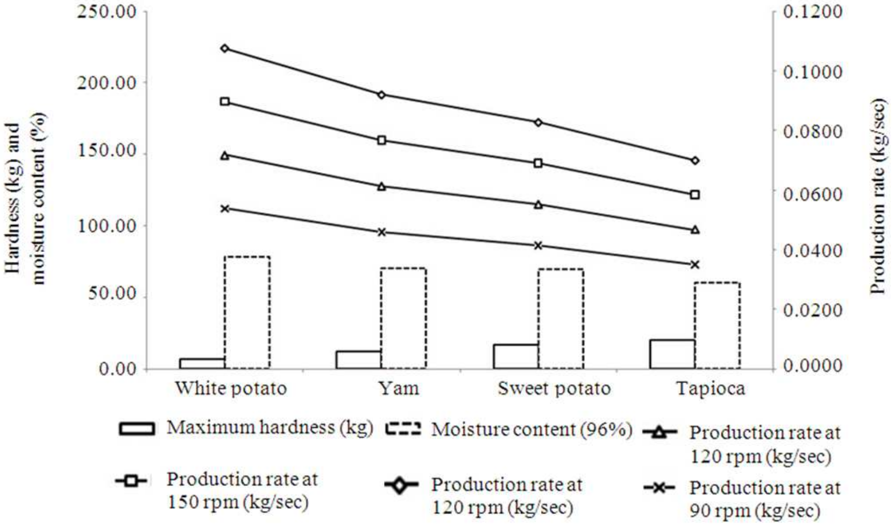


Fig. 4: Relationship of sliced production rate to hardness and moisture content for starchy vegetables

Table 2: Properties of hardness, solid density, pore volume and moisture content of the starchy vegetables

| Starchy vegetable | Hardness (kg) | Hardness (N) | Solid density (g/cm$^3$) | Pore volume (cm$^3$/g) | Moisture content (%) |
|---|---|---|---|---|---|
| White potato | 6. 67±0.27 | 65.43 | 1.1850±0.002 | 0.1561±0.002 | 78.14±0.15 |
| Yam | 12. 01±0.18 | 117.82 | 1.3092±0.004 | 0.2362±0.003 | 70.26±0.07 |
| Sweet potato | 16. 98±0.30 | 166.57 | 1.3877±0.004 | 0.2794±0.002 | 69.33±0.14 |
| Tapioca | 20. 08±0.51 | 196.98 | 1.4102±0.005 | 0.2909±0.002 | 59.97±0.13 |

Table 3: The production rate of grated outputs of starchy vegetables

| | Grated production rate (kg/sec) | | | |
|---|---|---|---|---|
| Starchy vegetable | At 180 rpm | At 150 rpm | At 120 rpm | At 90 rpm |
| White potato | 0. 3228±0.010 | 0.2690±0.009 | 0.2152±0.007 | 0.1614±0.005 |
| Yam | 0. 2758±0.016 | 0.2299±0.014 | 0.1839±0.011 | 0.1379±0.008 |
| Sweet potato | 0. 2482±0.009 | 0.2068±0.008 | 0.1654±0.006 | 0.1241±0.005 |
| Tapioca | 0. 2099±0.007 | 0.1749±0.006 | 0.1400±0.005 | 0.1050±0.003 |

Table 4: The production rate of sliced outputs of starchy vegetables

| | Sliced production rate (kg/sec) | | | |
|---|---|---|---|---|
| Starchy vegetable | At 180 rpm | At 150 rpm | At 120 rpm | At 90 rpm |
| White potato | 0. 1076±0.004 | 0.0897±0.003 | 0.0717±0.002 | 0.0538±0.002 |
| Yam | 0. 0919±0.005 | 0.0766±0.005 | 0.0613±0.004 | 0.0460±0.003 |
| Sweet potato | 0. 0827±0.003 | 0.0689±0.003 | 0.0551±0.002 | 0.0414±0.002 |
| Tapioca | 0. 0700±0.002 | 0.0583±0.002 | 0.0467±0.002 | 0.0350±0.001 |

Table 5: Estimated production time to produce one tonne of grated products

| | Production time (Hour) for a tonne of grated products | | | |
|---|---|---|---|---|
| Starchy vegetable | At 180 rpm | At 150 rpm | At 120 rpm | At 90 rpm |
| White potato | 0. 86 | 1.03 | 1.29 | 1.72 |
| Yam | 1.01 | 1.21 | 1.51 | 2.01 |
| Sweet potato | 1. 12 | 1.34 | 1.68 | 2.24 |
| Tapioca | 1.32 | 1.59 | 1.98 | 2.65 |

Table 6: Estimated production time to produce one tonne of sliced products

| | Production time (Hour) for a tonne of sliced products | | | |
|---|---|---|---|---|
| Starchy Vegetable | At 180 rpm | At 150 rpm | At 120 rpm | At 90 rpm |
| White potato | 2. 58 | 3.10 | 3.87 | 5.16 |
| Yam | 3.02 | 3.63 | 4.53 | 6.04 |
| Sweet potato | 3. 36 | 4.03 | 5.04 | 6.71 |
| Tapioca | 3.97 | 4.76 | 5.95 | 7.94 |

## DISCUSSION

**Hardness, solid density and moisture content:** The solid density value increase with increasing hardness values, which indicates higher value of solid density implies denser of solid matter that results in higher hardness of the starchy vegetables (Table 2). The result also showed that the solid density of the starchy vegetables was above the density of water ($1g/cm^3$). Studied by Sirisomboon *et al.* (2007) on the separation of nut shells from kernels after nut shelling could not be done by blowing air or floating in water due to the solid density of nut and kernel were slightly higher than water. Therefore, the solid density result obtained indicates that the separation of grated and sliced output also could not be done by floating in water if both of the grated and sliced outputs are collected at the same extraction collector. Thus, extraction of both grated and sliced outputs must be separated using two different ways.

All of the measured data on moisture content (dry basis) of the starchy vegetables were above 60% and the result obtained was similar to the Rubatzky and Yamaguchi (1997) results for white potato (78.4%), yam (70%), sweet potato (69.4) and tapioca (60%). Higher percentage of moisture content means that the vegetables are far from their brittle state in which materials with moisture content less than 10% would be classified as brittle (Blahovec, 2007). Brittle materials can be difficult to grate and slice because the crack formations in the vegetable texture are so frequent (Blahovec, 2007). Therefore, higher percentage of moisture content could ease grating and slicing and produce desirable outputs with precision qualities due to the high value of the modulus of elasticity. Higher moisture content can also ease the cutting process as the liquid can act as a lubricant, in reducing the friction and separating the cut items from the cutter blade.

It was observed that the hard, solid density and pore volume of the vegetables increased as the moisture content decreased (Table 2). Pore volume indicates the volume fraction of void space or air space inside a material. Changes of pore volume affect shrinkage phenomenon during drying of food material (Madiouli *et al*., 2011). Solid density increases with decreasing pore volume, since solid density is inversely proportional to true volume. Hence, higher pore volume indicates denser of solid matter that also results in higher hardness of the vegetables.

Lower values of moisture content indicated higher dry matter contents (percentage of total solids), which could result in hardening of the vegetables. Harder vegetables might need a higher force to cut or penetrate the material due to their low moisture content. The hardness and moisture content analysis can be concluded as the interrelations of hardness and moisture properties, which can be used by the food industries to identify and predict the production rate of starchy vegetables.

**Production rate analysis:** Most agricultural products cannot be used directly for consumption but can be supplied as raw materials for the subsequent food processing operations (Saravacos and Kostaropoulus, 2002). Two food processing operations that will be discussed here are grating and slicing processes of starchy vegetables. Hardness and moisture content data obtained in the previous section 3.1 could influence the production rate of the food processing system. This section will also observe the interrelations between the hardness and moisture properties to the production rate of the grating and slicing products.

The results showed that the grated and sliced production rate decreased with decreasing cutting speed. The grated and sliced production rate at 150, 120 and 90 RPM was approximately 83%, 67% and 50% respectively lower compared to the grated and sliced production rate at 180 RPM. It is obvious that lower speed will reduce the yield of the production rate. Thus, it is more appropriate to use higher speed of 180 RPM in this study; since production rate is high and based on the quality observation (in term of the sliced output thickness and grating output size) of the grated and sliced products was not affected due to speed changes from 90 to 180 RPM.

It was determined previously that the hardness value of tapioca was the highest, which reflected the grating and slicing production rate as being the lowest. Harder material might pose higher resistance to the grating and slicing process and thus required higher force to grate and slice, resulting in longer production time. Similarly, the white potato showed the fastest grating and slicing production rate due to it having the lowest hardness value.

Gamble and Rice (1988) carried out a study on moisture content with respect to the sliced thickness of potatoes. The effect of the sliced thickness of potatoes on moisture content during frying process shows the frying time was shorter with thinner sliced of potatoes (Gamble and Rice, 1988). This effect was due to moisture loss more rapidly during frying process (Gamble and Rice, 1988). This implied that the higher value of moisture content worked as a ‘lubricant’ to help the grating and slicing process run more smoothly, resulting in an increased production rate. Hence, adding water spraying could work as an accessory for smoother operation during grating and slicing process while increasing production rates.

All of the sliced production rates of the vegetables were approximately 67% lower compared to the grated production rate. This might be due to different sizes and the surface area of the grated and sliced outputs. All vegetables outputs were clearly cut either for grated or sliced output and none of the outputs were broken during the process. This could verify that all of the sample vegetables were not brittle due to the high percentage of moisture content (>10%) and consisted of a high value of the modulus of elasticity (Blahovec, 2007). Therefore, the vegetables with high percentage of moisture content could ease the grating and slicing process and produce desirable outputs.

It was appropriate to use higher speed in order to produce more products which could reduce the utilities and production cost. Therefore, these estimated production times could assist relevant food processing industries in predicting the whole production rate and magnitude of future cash flow, especially for the production of food chips and finger products.

## CONCLUSION

The hardness and moisture content data of the selected starchy vegetables were presented. It shows that the harder starchy vegetables had lower moisture contents. All starchy vegetables had moisture contents above 60%, which were far from the brittle state and suitable for grating and slicing process. Harder vegetables also resulted in lower production rate of grating and slicing. The properties of hardness and moisture content of the starchy vegetables are important design parameters for designing and fabricating the food processing equipments which relates to the grating and slicing process. The results found in this study could help relevant food processing industries in predicting the grating and slicing outputs, especially for the productions of food chips and finger products.

## ACKNOWLEDGEMENT

Research funding was funded by Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor Darul Ehsan, and Malaysia.

## REFERENCES

Chen, P. and Z. Sun, 1991. A review of non-destructive methods for quality evaluation and sorting of agricultural products. J. Agric. Eng. Res., 49: 85-98. DOI: 10.1016/0021-8634(91)80030-I

Barbosa-Canovas, G.V., P. Juliano and M. Peleg, 2012. Engineering properties of foods.

Rubatzky, V. and M. Yamaguchi, 1997. World Vegetables: Principles, Production and Nutritive Values. 2nd Edn., Chapman and Hall, New York, ISBN-10: 0412112213 pp: 704.

Lisinska, G. and W. Leszczynski, 1989. Potato Science and Technology. 1st Edn., Springer, London, New York, ISBN-10: 185166307X,, pp: 391.

Golubowska, G., 2005. Changes of polysaccharide content and texture of potato during French-fries production. Food Chem., 90: 847-851. DOI: 10.1016/j.foodchem.2004.05.032

Baik, O.D. and G.S. Mittal, 2003. Kinetics of tofu color changes during deep-fat frying. LWT-Food Sci. Technol., 36: 43-48. DOI: 10.1016/S0023-6438(02)00175-5

Taiwoa, K.A. and O.D. Baik, 2007. Effects of pre-treatments on the shrinkage and textural properties of fried sweet potatoes. LWT-Food Sci. Technol., 40: 661-668. DOI: 10.1016/j.lwt.2006.03.005

Somsen, D., A. Capelle and J. Tramper, 2004. Manufacturing of par-fried french-fries, part 3: A blueprint to predict the maximum production yield. J. Food Eng., 61: 209-219. DOI: 10.1016/S0260-8774(03)00150-X

Sirisomboon, P., P. Kitchaiya, T. Pholpho and W. Mahuttanyavanitch, 2007. Physical and mechanical properties of jatropha curcas l. Fruits, nuts and kernels. Biosyst., Eng., 97: 201-207. DOI: 10.1016/j.biosystemseng.2007.02.011

Blahovec, J., 2007. Role of water content in food and product texture. Int. Agrophysics, 21: 209-215.

Madiouli, J., J. Sghaier, D. Lecomte and H. Sammouda, 2011. Determination of porosity change from shrinkage curves during drying of food material. Food Bioproducts Process., 90: 43-51. DOI: 10.1016/j.fbp.2010.12.002

Saravacos, G.D. and A.E. Kostaropoulus, 2002. Handbook of Food Processing Equipment. 1st Edn., Springer, New York, ISBN-10: 0306472767, pp: 698.

Gamble, M.H. and P. Rice, 1988. The effect of slice thickness on potato crisp yield and composition. J. Food Eng., 8: 31-46. DOI: 10.1016/0260-8774(88)90034-9