RESEARCH PAPER

INTERNATIONAL JOURNAL OF PROCESSING AND POST HARVEST TECHNOLOGY
Volume 2 | Issue 2 | December, 2011 | 77-85

Influences of pre-treatments on quality attributes of yam chips

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SUMMARY : The process conditions were optimized for the preparation of hot air dried yam chips. The effects of blanching time (0, 1, 3 and 5 min) and blanching temperature (80 and 90 °C) as well as the drying temperature (70, 80 and 90 °C) on the drying kinetics as well as various quality attributes of yam chips *viz.* colour, texture and brown pigment accumulation and organoleptic evaluation were also investigated. It was found that drying took place entirely in the falling rate period. Longer blanching time and lower drying temperature resulted in better colour retention and led to chips of lower browning index. Blanching also reduced the hardness and fracturabilty of the product. The final product showed optimum texture attributes for the blanching treatment of 90°C for 3 minutes followed by the drying process at 80°C for 480 minutes.

How to cite this paper: Kumar, Vishal and Kumar, Manish (2011). Influences of pre-treatments on quality attributes of yam chips, *Internat. J. Proc. & Post Harvest Technol.,* **2** (2) : 77-85.

Research chronicle : Received : *20.06.2011;* **Sent for revision :** *22.08.2011;* **Accepted :** *25.10.2011*

KEY WORDS : Blanching, Browning index, Colour, Organoleptic, Texture

Yams (*Amorphophallus* spp.) is an important tropical tuber food crop rich in starch (Akanbi *et al.,*1996; Omonigho and Ikenebomeh, 2000). They have the highest rate of dry matter production per day and are major calorie contributors. Yam have also been used as health food and herbal medicinal ingredients in traditional Chinese medicine (Liu *et al.,* 1995). Yam extracts showed significant anti oxidative activity and modified serum lipid levels in humans. Yams are used to help treat diabetes mellitus (Hikino *et al.,* 1986 and Liu *et al.,* 1995) and promote the health of women after menopause (Araghiniknam *et al.,* 1996 and Mirkin, 1994). Several biological activities, such as anti-cancer (Ravikumar *et al.,* 1979 and Sung *et al.,* 1995), anti-thrombotic (Peng *et al.,* 1996 and Hsu *et al.,* 2003), anti-viral (Aquino *et al.,* 1991), hemolytic (Hsu *et al.,* 2003 and Santos *et al.,* 1997), hypercholesterolemic (Malinow, 1985 and Sauvaire *et al.,* 1991) and hypoglycemic (Kato *et al.,* 1995) have been documented.

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Because yams are regarded as health foods and not staple, it is feasible to develop a stable form of yam products to fulfill the health food market. To overcome the perishability of fresh yam tubers, due to their high moisture content and the seasonal nature of their production yams can be processed into dried products so that it could be available round the year for consumption and conveniently used in manufacturing formulated foods or capsules and other value added products for consumption(Ajibola *et al.,*1988 and Iyota *et al.,* 2001).

Yam chips can be a popular snacks and its production can generate a competitive industry like other snack products (Garayo and Moreira, 2002). Many works have been performed to study hot air drying of yam pieces of various shapes (Krokida *et al.,* 1998; McMinn and Magee, 1996 and Wang and Brennan, 1995). Drying as one of the most common preservation methods could, therefore, be a feasible alternative for production of low-fat or fat-free yam chips with desirable colour and textural characteristics. Conventional air-drying is energy intensive and consequently cost intensive because it is a simultaneous heat and mass transfer process accompanied by phase change (Barbanti *et al.,*1994). Hot air drying is an economical mechanical system of drying in which drying of food is done by ventilating hot air through wet food sample to accomplish removal of moisture from it. In heated air drying systems hot air is ventilated through a mass of agricultural product by forced convection method. The heat of drying air provides necessary energy for moisture removal from the product. During this process, air creates more vapour interior in parts of the products than the outer surface. The water- vapour pressure gradient between inside and the surface of the product is responsible for the drying of the water vapour removal (Siva and Buncha, 2003 and Hassini *et al.,* 2007).

Prior to drying most food products are usually subjected to one form of pretreatments; among other methods hot water blanching is one of the most common techniques. Blanching helps inactivate enzymes that lead to some quality degradations (Moreno-Perez *et al.,* 1996). Blanching also facilitates starch gelatinization that leads to the change of internal structure and influences the drying rate and quality of the dried product (Senadeera *et al.,* 2000). The combined effects of blanching and drying on the drying behavior and quality of the dried yam product are thus the interesting issues.

The present work is aimed at studying the effects of drying and blanching conditions on the drying kinetics and quality of yam chips in terms of colour, texture, and browning index, which can be used as an indicator of quality deterioration causing from excessive heat treatment (Cohen *et al.,* 1998).

EXPERIMENTAL METHODS

Physicochemical characterization of fresh yam :

Sample preparation :

Fresh yam of Gajendra variety was purchased from nearby local market. For the total dry materials determination in raw sample and for determining of the initial moisture content, the sample was heated in a drying oven (Model no- Indosaw-6745) at 105 ^{O}C for 48 h, according to AOAC method 934.06 (AOAC, 1990).

Prior to starting of each experiments, yam were washed, peeled, and sliced into 2.0 mm thickness slices using an electric slicer. The slices were given final circular shape of diameter 35 mm using a core borer. While providing the exact circular shape to the chips, some pulp were wasted which was recorded for finding the total wastage of the pulp *i.e* the process efficiency. Process efficiency was calculated for finding the wastage of material while finalizing the final product and it is the product of usage efficiency and pulp recovery efficiency. During the process for making chips, weight of raw, weight of skin, and weight of wasted pulp were taken with the help of precision electronic balance (Mettler AE 106, Least count :0.0001g).

$$\text{Process efficiency} = \text{Pulp recovery efficiency} \times \text{Usage efficiency}$$

$$\text{Pulp recovery efficiency} = \frac{\text{peeled weight of yam}}{\text{Total weight of raw sample}}$$

$$\text{Usage efficiency} = \frac{\text{weight of the chips}}{\text{weight of pulp}}$$

Pre-treatments :

The sliced chips were blanched in hot water at 80 and 90 °C for 0, 1, 3, and 5 min with a definite amount of potassium bi-sulphite (0.5%) and sodium chloride salt (2.0%) with the ratio of to water of 0.015 g/g. Chips were then immediately cooled down in cold water to 4 °C and placed on a paper towel to remove excess water prior to drying.

Polyphenoloxidase (PPO) and peroxidase (POD) activity and total phenol (TP) content :

PPO, POD and TP were determined using the methods described by Mestres *et al.* (2002), measuring the oxygen consumption kinetic at 460 nm with catechol as substrate and the discoloration kinetic with an optical density at 760 nm after reaction with folin reagent.

Experimental set-up and methods :

A hot air cabinet dryer was used for drying purpose. It consists of a stainless steel drying chamber, which is connected to an electric heater rated at 6.0 kW, which was used to heat up the air to the desired drying temperature; the heater was controlled by a PID temperature controller. The air velocity was controlled by a fan speed controller. In each experiment approximately 32 chips were placed on the tray with a dimension of 30 × 40 cm^2. Samples from the tray were collected at every 15 min interval for moisture content determination. Drying temperatures used were 70, 80, and 90 °C while the constant inlet air velocity of 1.0 m/s was used.

The samples were dried until reaching the final moisture content of around 3.5% (d.b.) (Caixeta *et al.,* 2002), which is similar to that of commercially available chips (Pringle™ and Parle™) of 2–3% (d.b.).

Moisture content (AOAC, 1990), colour, browning index, and hardness of the samples were measured. Preliminary test was also performed to evaluate the degree of starch gelatinization of chips after blanching.

Degree of starch gelatinization:

Degree of starch gelatinization was evaluated using the differential scanning calorimetry method. Approximately 15 mg of sample was placed in an aluminum pan. The sample was then scanned from 25 to 160 °C at a heating rate of 10 °C/min by a differential scanning calorimeter (DSC) (Mettler Toledo DSC 822^e, Switzerland). The degree of starch gelatinization was calculated using equation:

$$DG = \left(1 - \frac{\Delta H_g}{\Delta H_{row}}\right) x100$$

where DG is the degree of starch gelatinization (%), ΔH_g is the enthalpy of gelatinization of the sample (J/g), ΔH_{raw} is the enthalpy of gelatinization of the raw sample (J/g).

Colour measurement:

The colour of samples was analyzed by measuring the reflectance using a colorimeter (Hunters colour lab). The colorimeter was calibrated against a standard white plate before each actual colour measurement. For each sample at least five measurements were performed at different positions and the measured values (mean values) were compared with those of the same sample prior to drying. Three hunter parameters, namely, *L* (lightness), *a* (redness/greenness), and *b* (yellowness/blueness) were measured and colour changes were calculated by:

$$\Delta L = \frac{L - L_O}{L_O}, \Delta \mathbf{a} = \frac{a - a_O}{a_O} \, and \, \Delta \mathbf{b} = \frac{b - b_O}{b_O}$$

where *L*, *a*, *b* represent the lightness, redness and yellowness of the dried samples, respectively, while L_0, a_0, b_0 represent the initial values of the lightness, redness and yellowness of the sample prior to drying, respectively.

Browning index:

The browning index was determined using the procedure described by Hendel *et al. (*1955). The samples were ground and 2 g portion was extracted with 20 ml of 2 per cent acetic acid solution and then filtered through a filter paper (Whatman No. 3). An aliquot of the filtrate was mixed with an equal volume of acetone and filtered again. The absorbance of the extracted colour solution was measured at 420 nm using a spectrophotometer (Shimadzu, Model UV 2101 PC, Tokyo, Japan) using a 1 cm cell. The results are expressed in terms of the optical density.

Texture analysis :

The texture of chips was evaluated by a compressive test using a texture analyzer (Stable Micro System, TA.XT.Plus, UK). The test involved applying a direct force to the sample, which was placed on the hollow planar base. The force was then applied to the sample by a 5-mm spherical probe at a constant speed of 2 mm/s until the sample was cracked (Moreno-Perez *et al.,* 1996). Force–deformation data were recorded to determine the textural characteristics of the chip. The maximum force of break under the force–deformation curve indicated the hardness/crispness of the chip Aguilera *et al.,* (2004) Mendiola *et al.* (2007). All tests were performed in triplicate and the average values were reported.

Organoleptic evaluation

Dried chips were stored up to 3 months in polyethylene sheet bags at 30°C.Consumer acceptance test prior to storage studies was conducted using 9-point hedonic scale (Krokida *et al.,* 2001). The sensory quality of dried and rehydrated yam sample was evaluated by a trained panelist who evaluated the product for appearance, taste, flavours, aromas, texture and overall quality (Ranganna, 1999). The samples scoring an overall quality of 7 or above were considered acceptable and those receiving 6 or below 6 were considered unacceptable.

EXPERIMENTAL FINDINGS AND ANALYSIS

The results obtained from the present investigation are presented below:

Physicochemical characterization of fresh tubers:

Dry matter content ranged from 19.2 to.23.73 per cent (wet basis). Process efficiency was calculated for finding the wastage of material while finalizing the final product. During the experiments, weight of raw , its skin weight, weight of wasted pulp in the process of giving shape to the chips and weight of chips was measured. Process efficiency, usage efficiency and pulp recovery efficiency were found to be 75.68 per cent. 84.70 per cent and 89.36 per cent, respectively. were recorded.

Effect of blanching on chips:

In order to show the effect of blanching on product quality, various experiments were performed in hot air dryer with and without blanching. From peroxidase activity determination the results showed that peroxidase activity reduced drastically after blanching, even for 3 min. Thus, the effect of enzymatic browning during subsequent drying could be neglected in the case of blanched samples. Chips blanched at different temperatures and at various periods also had different degrees of starch gelatinization, which are shown in Table 1. Fig. 1, 2 and 3 show the effect of blanching temperature and blanching time on drying of yam. It was found that increasing blanching time can decrease drying time in dryers with air circulation. This phenomenon is due to the fact that in a convective dryer, the drying time is nearly large for unblanched samples and a resistant film layer may be formed on the surface of yam due to gelling of present starch. This film can reduce the mass transfer and hence increased the drying time. The unblanched samples didn't show a desirable appearance at all.

Table 1 : Degree of starch gelatinization of blanched chips

Blanching time (min)	Blanching temperature (^{0}C)	Degree of starch gelatinization (%)
0	-	0
1	80	63.62
3	80	69.83
5	80	84.22
1	90	68.85
3	90	79.94
5	90	94.86

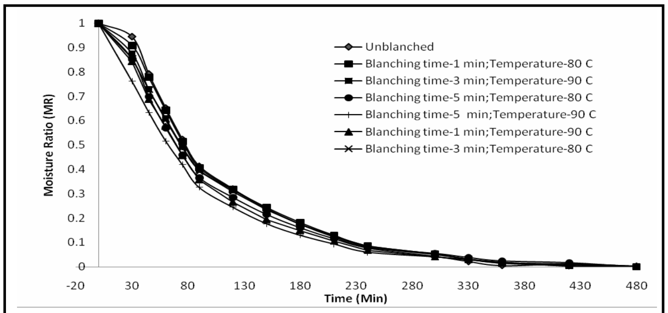

Fig. 1 : Drying curves of yam chips underwent blanching at (a) 0, (b) 1, (c) 3, and (d) 5 min at blanching temperature 80 and 90 0C in a hot air dryer at 70 °C

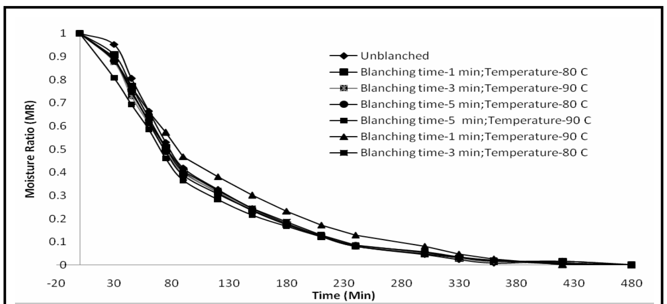

Fig. 2 : Drying curves of yam chips underwent blanching at (a) 0, (b) 1, (c) 3, and (d) 5 min at blanching temperature 80 and 90 0C in a hot air dryer at 80 °C.

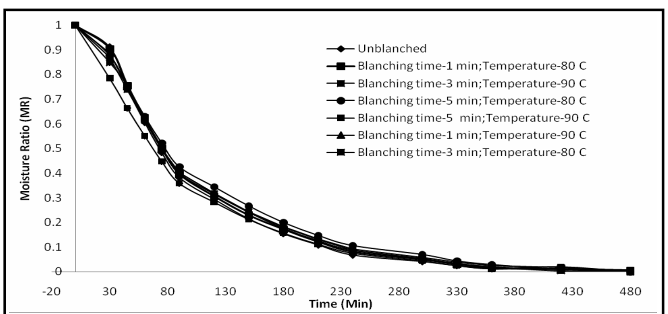

Fig. 3 : Drying curves of yam chips underwent blanching at (a) 0, (b) 1, (c) 3, and (d) 5 min at blanching temperature 80 and 90 ^{0}C in a hot air dryer at 90 °C.

Contrasting behaviour of polyphenoloxidase and peroxidase activities and total phenols content :

Polyphenoloxidase (PPO) and peroxidase (POD) activities and total phenol (TP) content varied to a large extent with the unit operations (Table 2). POD activity was significantly reduced during blanching (84.81% reduction in POD activity) whereas PPO was mainly reduced during drying. After drying, residual PPO and POD activities were at least one fourteenth of initial activities. TP content, on the other hand, increased significantly during drying (twice the initial value).

Table 2 : Physicochemical characteristics of yam

Characteristics	Raw yam slices	Blanched slices (3 min, 80^0)	Hot air dried blanched slices
Polyphenoloxidase activities (µmol O^2 min$^{?1}$ g$^{?1}$)	32.21	27.23	2.39
Peroxidase activities (mDO s$^{?1}$ g$^{?1}$)	143.6	10.3	6.8
Total phenols content (µM g$^{?1}$ db)	2.3	2.7	4.6

PPO and POD activities samples were within the range reported by Mestres *et al.* (2002): 10–50 µmol O_2 min^{-1} g^{-1} and 60–600 mDO s^{-1} g^{-1}, respectively. The lack of effect of blanching at 80 °C for 3min on PPO activity was consistent with results of Ikediobi and Obasuyi (1982), Yang *et al.,* (2001) and Yang *et al.,* (2001b), who showed that 80 per cent of PPO activity remained after 10 min at 70 °C. In contrast, PPO activity decreased dramatically after hot air drying at 80 °C for 8 hours. This is in agreement with results of Omidiji and Okzupor (1996) and Ikediobi and Obasuyi (1982) and can be linked to a long-term PPO degradation mechanism.

The total phenol content of the oven-dried samples was slightly higher than the values (0.5–2.5 ìmol g^{-1} db) obtained by Mestres *et al.* (2002). Total phenol content increased during drying. During this operation, peroxidase activity was low (between 10.3mDO s^{-1}g^{-1} at the start of drying and 6.8 mDO s^{-1}g^{-1} at the end of drying while PPO activity decreased dramatically (from 27.23 ìmol O_2 min^{-1}g^{-1} to 3.39 ìmol O_2 min^{-1}g^{-1}). This tends to indicate that phenol production was not dependent on enzymatic activity. However, the phenol content of the dried slices was highly and positively correlated with the POD activity of the fresh tubers. This suggests a two-step reaction mechanism, leading to an increase in the total phenol content of yam slices. The first step, occurring before blanching is completed, would be mainly POD-dependent and lead to phenol precursors, while the second, occurring during drying, would be a long-term non-enzymatic phenomenon.

A correlation was observed between the brown index and the total phenol content of the dried chips and between the brown index and the peroxidase activity of the blanched chips while PPO activity was not found to be significantly involved. Because of this, mainly the brown index of yam chips will be discussed. The brown index increased significantly with drying temperature (from 0.0398 to 0.555 for the mean value) whereas blanching temperature and blanching time had no significant effect. In contrast, the yellow index of yam chips decreased when the total phenol content of oven-dried flour and the peroxidase activity of blanched yam chips increased. Thus, the increase in discoloration when yam is blanched should be linked to thermal degradation of originally colourless complex phenolics (proanthocyanidins and lignins) to coloured phenols (Swain and Hillis, 1959).

Drying kinetics of yam chips:

Raw and blanched yam chips with initial moisture contents in the range of 76.27 -80.80 per cent wet basis (or 321.41 to 420.83% dry basis) were dried until reaching their equilibrium moisture contents. Fig. 1,2, 3 show the drying curves of yam chips undergoing hot air drying at various conditions. It was found that drying at higher temperature took shorter time to reach the desired moisture content because of a larger driving force for heat transfer. Drying rate showed an increase at the beginning of the process due to sample heating. After an initial short period the drying rate reached a maximum value and then it followed falling rate in all drying conditions. No constant drying rate period was observed. Similar results were reported by previous researchers (Ajibola *et al.,*1988; Kaya *et al.,* 2007; Lucia *et al.,* 2007; Pankaj and Sharma, 2006; Schultz *et al.,* 2007). Similar results were observed for chips underwent any blanching conditions. However, it was found that the blanched samples dried faster than the unblanched one. This behavior was probably due to structure softening due to blanching that might facilitate water removal (Severini *et al.,* 2005 and Potter and Hotchkiss, 1998). When the tissue was blanched or cooked the cells might become more permeable to moisture. However, excessive blanching time decreased the rate of moisture removal. This might be due to the effect of starch gelatinization, structural changes, and water content absorbed during blanching. Higher degree of starch gelatinization might affect the cell structure and increase the internal resistance to moisture movement, which resulted in lower diffusivity (Mate *et al.,* 1998). Therefore, the samples blanched for 1 min resulted in the highest drying rates followed by those blanched for 3 and 5 min, respectively; unblanched yam chips had the lowest drying rates for all drying conditions. However, it was found that, at higher drying temperatures, the drying rates of samples treated with different blanching periods were not obviously different. So, the effect of blanching was greater than the effect of drying temperature.

Quality of dried yam chips :

Colour:

Colour deterioration of fruits during thermal processing is due mainly to pigment degradation and browning reaction. Since carbohydrate (reducing sugar) and protein (amino acid) are principle components in raw yam, possible browning reaction that could occur during drying is Maillard reaction. Table 3 illustrates the colour changes of yam chips in terms of colour differences, $\Delta L/L_0$, $\Delta a/a_0$, and $\Delta b/b_0$. Since the enzymes that caused the quality degradation were destroyed during blanching, the non-enzymatic browning was considered a major cause of colour changes of dried yam chips.

All data were analyzed using the analysis of variance (ANOVA). The Factorial's test was used to establish the multiple comparisons of mean values. Mean values were considered at 95 per cent significance level (á = 0.05).

In the case of lightness, it was found that the blanching time and blanching temperature did not as significantly affect the change of lightness as drying temperature did. However, the reduction of lightness ($\Delta L/L_0$) was greater at higher drying temperatures for both blanching processes. This is because non-enzymatic browning reaction was accelerated by temperature.

Regarding the change of redness of dried yam chips the drying temperature, blanching time and their interaction had significant influences on this colour parameter under certain conditions. It was observed that all dried yam chips were redder than the fresh yam. However. regarding the effect of the drying temperature, higher drying temperature led to an increase of *a* value for all blanching conditions. The above results were due to Maillard reaction or heat damage that occurred more at higher drying temperatures. The changes of redness of blanched chips treated at 90 °C were significantly higher than those at 70 °C but did not statistically differ from those at 80 °C.

For the effect of blanching unblanched chips had higher $\Delta L/L_0$ and *a* values than those of blanched samples and thus resulted in greater changes of $\Delta L/L_0$ and $\Delta a/a_o$ values at all drying temperatures. Blanching reduced the $\Delta L/L_0$ and *a* values of yam chips due to the leaching out of reducing sugars, which are the substrates of Maillard reaction, prior to drying and thus minimized the non-enzymatic browning reaction and led to less red chips. These results are similar to those reported by Pedreschi *et al.* (2008).

The yellowness (*b* value) of dried yam chips was affected by drying temperature and blanching time while

Table 3 : Effects of drying method, drying temperature, blanching time and blanching temperature on colour changes and browning index of dried yam chips

Drying temp (°C)	Blanching time (min)	Blanching temperature (^{0}C)	$\Delta L/L_0$	$\Delta a/a_0$	$\Delta b/b_0$	Browning index
70	0	-	0.791 ± 0.012	1.235 ± 0.067	-0.797 ± 0.085	0.081 ± 0.012
	1	80	0.105 ± 0.047	0.583 ± 0.042	0.683 ± 0.097	0.070 ± 0.042
	1	90	-0.0963± 0.032	0.560 ± 0.025	0.665 ± 0.022	0.068 ± 0.002
	3	80	0.043 ± 0.002	0.598 ± 0.054	0.514 ± 0.043	0.036 ± 0.011
	3	90	-0.0364± 0.026	0.584 ± 0.052	0.499 ± 0.013	0.0387 ± 0.033
	5	80	0.0731 ± 0.066	0.656 ± 0.033	0.596 ± 0.062	0.042 ± 0.056
	5	90	-0.0739 ± 0.007	0.679 ± 0.009	0.569 ± 0.046	0.0398 ± 0.023
80	0	-	0.798 ± 0.032	1.336 ± 0.008	0.810 ± 0.045	0.206 ± 0.054
	1	80	0.183 ± 0.017	0.865 ± 0.053	0.651 ± 0.044	0.195 ± 0.027
	1	90	-0.175 ± 0.041	0.858± 0.046	0.643 ± 0.017	0.188 ± 0.034
	3	80	0.110 ± 0.056	0.978 ± 0.076	0.442 ± 0.030	0.134 ± 0.045
	3	90	-0.096 ± 0.028	0.919 ± 0.005	0.440 ± 0.037	0.150 ± 0.018
	5	80	0.191 ± 0.078	1.030 ± 0.022	0.617 ± 0.049	0.133 ± 0.067
	5	90	-0.188 ± 0.067	0.984 ± 0.061	0.601 ± 0.035	0.245 ± 0.008
90	0	-	0.846 ± 0.034	1.897 ± 0.027	-0.826 ± 0.023	0.555 ± 0.030
	1	80	0.261 ± 0.024	1.322 ± 0.036	0.359 ± 0.027	0.411 ± 0.041
	1	90	-0.247 ± 0.063	1.296 ± 0.046	0.346 ± 0.0.28	0.425 ± 0.44
	3	80	0.207 ± 0.023	1.513 ± 0.017	0.239 ± 0.063	0.396 ± 0.021
	3	90	-0.198 ± 0.021	1.487 ± 0.013	0.266 ± 0.044	0.416 ± 0.005
	5	80	0.275 ± 0.047	1.497 ± 0.008	0.313 ± 0.008	0.306 ± 0.003
	5	90	-0.266 ± 0.019	1.523 ± 0.066	0.299 ± 0.054	0.321 ± 0.044

the blanching temperature did not show any significant influence on the *b* value. The unblanched yam chips showed an obvious reduction of the yellowness (lower $\Delta b/b_0$ values) after drying. In other words, blanched yam chips showed relative stability of yellowness. Yam chips dried at lower temperatures tended to have higher values of yellowness than those dried at higher temperatures. It was also observed that shorter blanching time led to higher *b* values but the results were again not significantly different.

Browning index

The effects of blanching and drying temperature on the browning index of yam chips are shown in Table 3. Drying resulted in a high browning index at higher drying temperatures. This is due to the difference in surface temperature of yam during drying. In the constant drying rate period the surface temperature of yam chips undergoing hot air drying at 70, 80, and 90 °C were equal to the wet-bulb temperature, which was 43, 47 and 52 °C, respectively. As the drying temperature increased, of course, the wet-bulb temperature also increased. This increase in turn led to larger differences in browning index between the chips at higher drying temperatures. The highest value of browning index was obtained in the case of air-dried sample at 90 °C. A higher degree of non-enzymatic browning occurring during hot air drying might be due to both Maillard reaction and ascorbic acid oxidation.

The results of the browning index were also related to the colour changes, especially the change of redness. The results showed similar trends for both physical and chemical changes. From the results of colour changes and browning index it might be concluded that drying resulted in significant chemical damage of yam chips.

Texture:

Chip manufacturers are often interested in studying the effect of on hardness of the chips which is the maximum breaking force, and the results are shown in Table 4 and Fig. 4. It was found that blanching temperature and blanching time and drying temperature significantly affected the hardness of yam chips. Generally, blanching caused starch gelatinization, softening of structure and led to less hardness of dried starchy products. It was observed in this work that unblanched chips had the maximum hardness in all cases; blanching led to significantly less hard chips. This might be due to the effect of casehardening developed during moisture removal.

Table 4 : Effects of drying temperature and blanching on hardness of dried yam chips

Drying temp (°C)	Blanching time (min)	Blanching temperature (^{0}C)	Hardness (N)	Time to fracture (sec)
70	0	-	6.107	0.490
	1	80	4.898	0.386
	1	90	4.771	0.374
	3	80	5.142	0.367
	3	90	4.725	3.212
	5	80	4.993	0.312
	5	90	4.4270	2.866
80	0	-	5.935	0.395
	1	80	4.605	0.344
	1	90	4.520	0.310
	3	80	4.653	0.318
	3	90	4.476	0.303
	5	80	4.693	0.190
	5	90	4.491	2.664
90	0	-	5.128	0.370
	1	80	4.679	0.332
	1	90	4.056	0.2885
	3	80	3.421	0.2891
	3	90	3.013	0.2694
	5	80	3.113	0.2452
	5	90	2.918	0.200

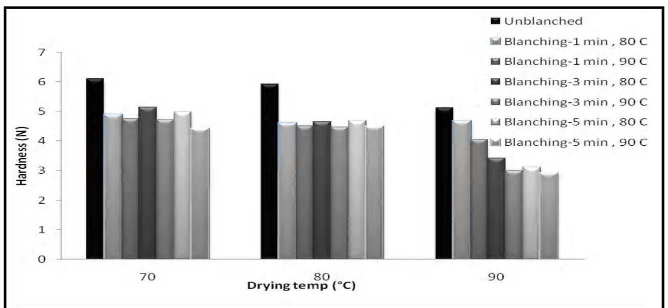

Fig. 4 : Hardness of yam chips blanched for different periods and temperatures and underwent hot air drying at different drying temperatures

For the effect of drying temperature it was found that drying temperature significantly affected the hardness, especially at higher temperatures. The hardness of the samples dried at 90 °C was lower than that dried at 70 °C but was not significantly different from that dried at 80 °C. This might be either due to the effect of puffing that occurred more at higher temperatures and probably increased the porosity and resulted in a decrease of hardness and less shrinkage of the samples or due to a large variation of the experimental results caused by the non-uniform or heterogeneous nature of raw yam.

It was found that chips treated with at air drying temperature at 90 °C (with 5 min blanching time at 90°C), required the lowest force of compression were still harder than the commercial products (For Lay™ and Parle™ the hardness were 1.861 and 1.934 N, respectively).

Also, the time of break is an indication of fracturabilty or crispiness, and so may also be of interest. The shorter the time to fracture, the more easily the product is fractured. Hence, in terms of crispiness, samples dried at 90 °C took less time to fracture than that dried at 80 and 70 °C .

Consumer acceptance test was conducted for the yam chips using 9-point hedonic scale. The result of the sensory analysis showed that 45 per cent of the responses marked the sample as "like very much" and remaining 55 per cent as "like moderately" (significant at $p<0.05$ level). Sensory evaluation of all the samples were found to be acceptable but the dried sample (90 °C hot air drying, 80°C blanching temperature and 3 min blanching time) showed high sensory scores as compared to other samples with respect to their colour, flavour, texture (crispness) and overall quality.

Conclusion:

The effects of drying and blanching conditions on the drying kinetics and quality of yam chips were examined in this study. In terms of drying kinetics blanching time as well as drying temperature were found to have effects on the moisture reduction rate of samples. It was found that blanching could increase the drying rates. The quality study showed that blanching led to better colour retention, less hardness and lower degree of browning of chips. In addition to the drying temperature pretreatments also possessed significant effects on the drying rates, especially at lower drying temperatures. Regarding the textural quality the hardness of dried chips was significantly influenced by the pretreatment methods but was lower at higher drying temperature. The crispness increased as the drying temperature increased but the toughness decreased with increased drying temperature.

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