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Physico-chemical characteristics of VitAto™ flour from different drying processes

(Pencirian fiziko-kimia tepung VitAto™ daripada proses pengeringan berbeza)

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Abstract

The physico-chemical characteristics (minerals and vitamins, colour, total sugar, reducing sugar, total starch, solubility, swelling power) and size of flour granules from different drying types (hot-air dried and drum dried) on selected sweet potato variety (VitAto™) were investigated. VitAto™ was collected locally in Malaysia. Calcium, magnesium, phosphorus, potassium, sodium, sulphur, zinc and vitamin C contents in VitAto™ flour using drum dried technique were significant higher (p <0.05) than hot-air dried flour. Drum drier technique showed a higher content of total starch (36.55 ± 0.89) and swelling power and solubility as the temperature increased. Total sugar (76.57 ± 0.67) and reducing sugar (25.02 ± 0.09) contents of VitAto™ flour by drum dried process was also higher than hot-air flour. The colour parameters showed that the L* value that measured brightness (76.57 ± 0.67) and b* values (52.93 ± 5.17) for drum dried flour were significantly higher (p <0.05) than hot-air flour. Scanning electron microscopy (SEM) analysis showed that the granular of flour from drum drier technique had irregular shapes with an average size ranging from 50 – 200 μm. This gives an idea about higher solubility value of drum dried flour than hot-air flour. This study showed that drum dried flour can be promoted as a potential drying technique in the food industry.

Keywords: physico-chemical contents, VitAto™ flour, hot-air drying, drum drying, size of granule

Introduction

Sweet potato (*Ipomoea batatas*) has been cultivated in Malaysia for many years (Salma and Zaidah 2006). It is usually used as a basic ingredient in making snacks, flour and traditional confectionery (*kuih*) and also processed into chips where it is thinly sliced and deep-fried. It is nutritious and contains high β-carotene, substantial amounts of ascorbic acid and minerals (Jasim and Hosalli 2006). Sweet potato can also be used as supplementary food for infants and can be compared to other cereal based baby foods such as wheat due to its hypoallergenic effect (Maleki 2001).

There are a few varieties of sweet potatoes available in Malaysia. Researchers at Malaysian Agriculture Research and Development Institute (MARDI) have shown that the tubers of Gendut, Merah Manis and Jalomas varieties have good potential for their functional and nutritional

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values (Salma and Zaidah 2006). MARDI's latest variety, VitAto™ , is known to have high value of vitamin A (β-carotene). It is delicious when eaten fried or steamed. VitAto™ can be processed into fries, cakes, buns and muffins. Therefore, knowledge on utilising sweet potato as flour, proximate value, fibre and starch are important.

Sweet potato flour is prepared by drying the peeled slices in a hot-air drier or by drum drying of cooked sweet potato mash into flakes followed by milling and sieving (Wolfe 1992). Dehydrated sweet potato can be used for various baked products such as pancakes, cakes, flat breads, cookies, fritters or bread to partially replace wheat flour and as an alternative market outlet for farmers selling the raw sweet potatoes (Van Hal 2000). Dehydrated sweet potato has commonly been obtained by hot-air drying, which allows rapid and massive processing although it greatly affects the sensory and nutritional characteristics of the end product. Dehydration is one of the oldest methods of food preservation (Adams 2004) and converting sweet potato into flour could contribute to minimal losses of fresh product and is less bulky and more stable than the perishable fresh root (Maruf et al. 2010).

Hot-air drier or cabinet drier method is normally chosen and used as it is a conventional, simple, easier and cheaper method of drying. Flour is conventionally prepared by drying slices or dices of sweet potato using a hot air dryer at a suitable temperature and time before grinding to become a powder form. Another drying technique that has been used for drying the sample is by using a drum drier.

Drum drier is a continuous indirect heating style drier. The basic mechanism is using a liquid feeder to spread the liquid or paste based material to be dried onto the surface of a steam heating drum. After that, it is rotated together after half of the cycle, and then a scraper is used to scrap off the dried membrane that is adhered to the drum surface. Then, the dried membrane is placed to a conveyor and transfer to the crusher to make into flake or powder form.

The aim of this study was to investigate the effects of the drum dried flour and hot-air dried flour on the physicochemical characteristics (minerals and vitamins, colour measurement, reducing sugar, solubility and swelling power) and size of flour granules using scanning electron microscopy on VitAto™ flours. All minerals, vitamin A, vitamin C, total starch, total sugar and reducing sugar of both processes were determined and compared. Colour measurement of the flour was also performed to investigate the brightness of the flour. In order to use the flour as an ingredient, the swelling power and solubility patterns were determined. This study also determined the size of granules based on scanning electron microscopy (SEM) images.

Materials and methods

Raw materials

Fresh VitAto™ at commercial maturity (3.5 months after planting) was purchased from local growers at Besut, Terengganu, Malaysia. Tubers were stored at room temperature for not more than 5 days before it was used for further process. Then the VitAtoes™ were cleaned under running tap water, dried and stored at room temperature before use.

Preparation of drum dried flour

The preparation of VitAto™ flour using drum dried (Simon Dryers Ltd, Nottingham, England) method was carried out as described by Ramesh et al. (2006). Fresh tubers were washed using the automated vegetable washer for 20 min. Cleaned VitAto™ tubers were cut and immediately immersed in clean filtered water to reduce any browning reaction followed by heat treatment at 100 °C using clean steam for 35 min. Heat treatment was considered complete when the central point of VitAto™

cuts reached 90 °C using a thermometer. Steamed VitAto™ cuts were mashed into the puree using bowl chopper for 80 s. VitAto™ puree was then filled and sealed in plastic packs containing 5 kg per pack. VitAto™ puree was poured onto the drum dryer roller at a speed level of 27.78 s/rev at a steam pressure of 6 Bar. VitAto™ flakes were immediately packed in aluminium packets and sealed in order to avoid excess absorption of air into the flakes and ground using a flour grinder (0.02 mm). The flour was packed using aluminium packaging materials and stored at 4 °C in air tight containers prior to analysis.

Preparation of hot air dried flour

The preparation of VitAto™ flour using hot air drier (RXH-B-1 (Jiangyin Hongda, Jiangsu, China) method was carried out as described by Ramesh et al. (2006) with a modification of drying temperature. The fresh VitAto™ tubers were washed using the automated vegetable washer for 20 min. Each tuber was cut into three parts to remove any unnecessary defects. The VitAto™ cuts were then sliced (0.5 cm x 0.5 cm) and the strips were immediately soaked in clean filtered water. The VitAto™ strips were tossed and spread. The temperature of hot air drier was set at 60 °C for the first 10 h and later increased to 70 °C for the final 9 h of drying. These steps of drying could ensure very low moisture content in the end product in order to retain the quality of the flour. The dried VitAto™ sticks were then ground using a hammer mill grinder (0.02 mm). The flour was packed using aluminium packaging materials and stored at 4 °C in air tight containers prior to analysis.

Determination of minerals, vitamin C and Vitamin A (β-carotene)

The mineral elemental constituents, calcium, cuprum, ferum, magnesium, phosphorus, potassium, selenium, sodium, sulphur and zinc (Ca, Cu, Fe, Mg, P, K, Se, Na, S and Zn) in samples were analysed using an atomic absorption spectrophotometer (Hitachi 26100, Tokyo, Japan) by acid digestion of the ash samples (AOAC 2000). Vitamin C and vitamin A were analysed according to AOAC (2000).

Determination of total starch, total sugar, reducing sugar and colour

Starch was isolated from fresh roots and the processed flours by water steeping method and dried using the solvent exchange method as described by Badenheizen (1964) with minor modifications. The total sugar and reducing sugar values were measured using Clegg-anthrone analysis (Clegg 1956) method with minor modifications and dinitrosalicylic acid method (Miller 1959) with modifications. The absorbance was measured using a UV visible spectrophotometer (Labomed INC) with glucose as a standard. Each analysis was performed in triplicate. For colour measurement, the colour scale of food ingredients used by CIELAB for measuring the degree of lightness (L*), the degree of redness or greenness (a*) and the degree of yellowness or blueness (b*) was used for comparison. For many food ingredients, L is used for darkness evaluation (100 = white and 0 = black). Samples of flours were subjected to colour analysis by three measurements in duplicate with the Minolta reflectance colorimeter Chroma Meter Cr-200 (Minolta Corp. Ramsey, NJ). The results of each measurement are the means of three instrument repetitions. The instrument was calibrated against a standard white reference plate.

Determination of swelling power and solubility

Both flours were prepared in a glass tube and heated to 30, 50, 70, and 90 °C respectively, for 30 min with shaking every 5 min, left to cool to room temperature and centrifuged for 15 min at 3,000 *g*. The supernatant was decanted, and the residual volume was determined. The solid part was dried in an oven for 2 h at 130 °C.

Swelling power and solubility patterns were determined using the method described by Unnikrishnan and Bhattacharya (1981) with slight modifications.

Scanning Electron Microscopy (SEM) analysis

The microstructure of both granule samples was mounted on metallic stubs, gold coated with sputter coater (Polaron Sputter Coat System, Model E5-10011, England) and viewed under SEM XL 30 ESEM Philips.

Statistical analysis

Data were analysed using general linear model of Duncan's least significant test to determine the differences between means among samples. Differences at $p < 0.05$ were considered as significant (SAS 2002).

Results and discussion

Minerals and vitamins content

Table 1 shows amounts of minerals, vitamin C and vitamin A (β-carotene) in drum dried and hot air dried VitAto™ flour. Minerals and vitamin C content of drum dried VitAto™ flour revealed significantly higher concentrations than hot air dried VitAto™ flour. No significant differences were found for magnesium (Mg), selenium (Se) and zinc (Zn) contents among the drying processes. However, results for Cu, Fe and Vitamin A (β-carotene) for hot-air dried VitAto™ flour were significantly higher than drum dried flour. The lower amount of vitamin A content in drum dried VitAto™ flour (4,718.28 μg/100 g) could be due to the continuous and high temperature process. According to Ahmed et al. (2010) and Michael and Wilson (1997), increasing drying temperature for all flours will affect carotenoid contents.

Total starch, total sugar, reducing sugar and colour determination

Drum dried VitAto™ flour had a higher content of total starch (36.55 mg/100 g), total sugar (76.57 mg/100 g) and reducing sugar (25.02 mg/100 g) than hot air dried VitAto™ flour. However, there were no significant differences at $p < 0.05$ among both drying techniques. This observation

Table 1. Minerals and vitamins content of hot-air dried and drum dried flour

Parameter	Hot-air dried flour	Drum dried flour
Calcium (Ca) (mg/100 g)	10.93 ± 0.07a	12.09 ± 0.04b
Cuprum (Cu) (mg/100 g)	0.15 ± 0.18a	0.07 ± 0.00b
Ferum (Fe) (mg/100 g)	0.13 ± 0.04a	0.01 ± 0.00b
Magnesium (Mg) (mg/100 g)	4.10 ± 0.06a	4.38 ± 0.02a
Phosphorus (P) (mg/100 g)	10.08 ± 0.03a	12.08 ± 0.19b
Potassium (K) (mg/100 g)	43.78 ± 1.46a	49.38 ± 0.75b
Selenium (Se) (mg/100 g)	0.00005a	0a
Sodium (Na) (mg/100 g)	10.71 ± 0.03a	12.01 ± 0.44b
Sulphur (S) (mg/100 g)	1.71 ± 0.09a	2.84 ± 0.10b
Zinc (Zn) (mg/100 g)	0.04 ± 0.00a	0.05 ± 0.00a
Vitamin C (mg/100 g)	43.43 ± 1.48a	46.65 ± 0.67b
Vitamin A (β-carotene) (ug/100 g)	5,385.57 ± 0.04a	4,718.28 ± 0.03b

All data expressed as mean ± standard deviation (sd) in dry weight basis. Means followed by different lowercase letters in each row are significantly different among drying processes ($p < 0.05$)

was similar and consistent with Van Hal (2000) and Maruf et al. (2010) as there were no significant differences in the total starch, total carbohydrates and sugar content of all samples at different drying temperatures.

The Hunter colour parameters, L*, a* and b*, which were used to compare the VitAto™ flours (*Table 2*). have been widely used to describe colour changes during dehydration of fruit and vegetable products. The colour parameters showed that the L* and b* values in drum dried VitAto™ flour were significantly higher than those observed in hot-air dried VitAto™ flour. Although Hunter L* values decreased with increasing drying temperature, the lighter colour of hot-air dried VitAto™ flour is strongly due to the long duration of time during the drying procedure. Besides, it could also be due to the retardation of enzymatic and non-enzymatic reactions (Yongjie and Meiping 2005) and caramelisation, oxidation or isomerisation of carotenoids (Michael and Wilson 1997).

Swelling and solubility

Table 3 shows the results of swelling power (SP) and solubility index (SI) for both techniques. The SP and SI of both flours increased as the temperature increased. VitAto™ flour from drum drier technique had higher SP and SI than hot-air dried flour.

Table 2. Total starch, total sugar, reducing sugar and colour determination of samples

Parameter	Hot-air dried flour	Drum dried flour
Total starch (%)	35.07 ± 0.27a	36.55 ± 0.89a
Total sugar (%)	70.52 ± 2.34a	76.57 ± 0.67a
Reducing sugar (%)	24.11 ± 0.34a	25.02 ± 0.08a
Colour determination	L* = 74.42 ± 1.81a a* = +0.88 ± 0.38a b* = +26.34 ± 1.2a	L* = 84.42 ± 1.66b a* = +1.03 ± 1.19a b* = +52.93 ± 5.17b

All data expressed as mean ± standard deviation (sd) in dry weight basis. Means followed by different lowercase letters in each row are significantly different among drying processes (p <0.05).
L* = measurement of brightness to black (0 to 100);
a* = red-green colour (+a = indicating redness; -a = indicating greenness);
b* = yellow-blue colour (+b = indicating yellowness; -b = indicating blueness).
Mean ± standard deviation (n = 3)

Table 3. Solubility Index (SI) and Swelling Power (SP) of samples

Temperature (°C)	Hot-air dried flour		Drum dried flour	
	SI (%)	SP (g/g)	SI (%)	SP (g/g)
1 (30 °C)	24.17 ± 5.13	4.46 ± 0.15	51.54 ± 3.21	4.60 ± 0.25
2 (50 °C)	25.03 ± 7.14	4.51 ± 0.24	52.21 ± 8.29	5.21 ± 0.17
3 (70 °C)	27.77 ± 0.80	8.75 ± 0.41	52.38 ± 9.06	7.99 ± 0.04
4 (90 °C)	38.89 ± 0.11	10.02 ± 0.17	54.26 ± 0.45	10.28 ± 0.19

All data expressed as mean ± standard deviation (sd) in dry weight basis

The pattern of solubility of VitAto™ flour from drum drier technique increases consistently with increasing temperatures (*Figure 1*). However, the solubility of hot-air dried VitAto™ flour increases much faster when the temperature is increased higher than the drum dried VitAto™ flour. The enormous difference between native and processed sweet potato flour in the solubility pattern appears to be the basis for differences in their functional properties, thus making them usable for the preparation of various end products (Ramesh et al. 2006).

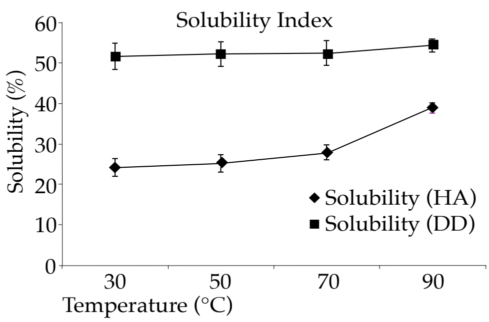

Figure 1. Solubility Index (SI) pattern for VitAto™ flour using hot-air dried and drum dried techniques

The pattern of SP for VitAto™ flour from both techniques did not show any difference (*Figure 2*). The increase in swelling and solubility can be attributed to the variation in the degradation of starch during thermal treatments. According to Tan and Chinnaswamy (1993), increase in swelling and solubility properties can be attributed to the degree of macromolecular disorganisation and also to variations in the degradation of starch during thermal treatments. However, the low swelling power is also due to the presence of a large number of crystallites, which will increase granular stability, thereby reducing the extent of granular swelling (Hoover and Ratnayake 2002).

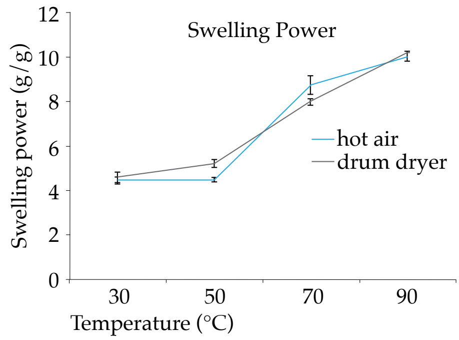

Figure 2. Swelling Power (SP) pattern for VitAto™ flour using hot-air dried and drum dried techniques

Size of granule by using SEM

Morphological and size of granules of both flours were captured by using Scanning electron micrographs (SEM) which showed considerable structural differences (*Figures 3 and 4*). *Figure 3* shows that the granules of hot-air dried VitAto™ flour were smaller and more rounder than drum dried VitAto™ flour granules with a spherical size (20 – 100 μm). The granules of drum-dried VitAto™ flour were irregular in shape, larger than hot-air dried flour granules and the size ranged from 50 – 200 μm (*Figure 4*).

The morphological features of drum dried and hot-air dried starch granules showed considerable structural differences, although having gone through different process conditions and severity of heat treatment. The disruption of the granules happening during thermal treatment could have resulted in the hollowness of the drum dried granules. Consequently, the broken granules of drum dried VitAto™ flour could be responsible for better hydration and complete gelatinisation of starch granules (Ramesh et al. 2006) and therefore, make the higher solubility value than hot-air dried VitAto™ flour.

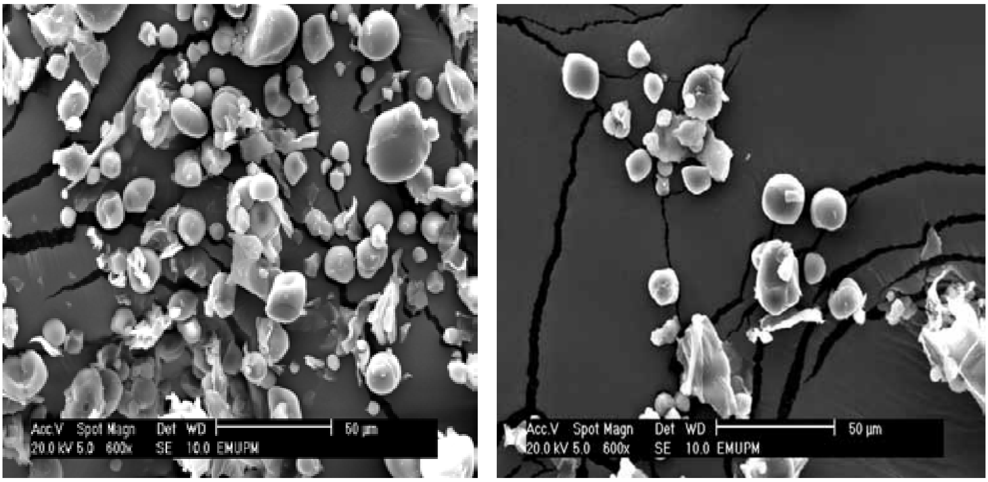

Figure 3. Scanning Electron Microscopy (SEM) of hot-air dried VitAto™ flour

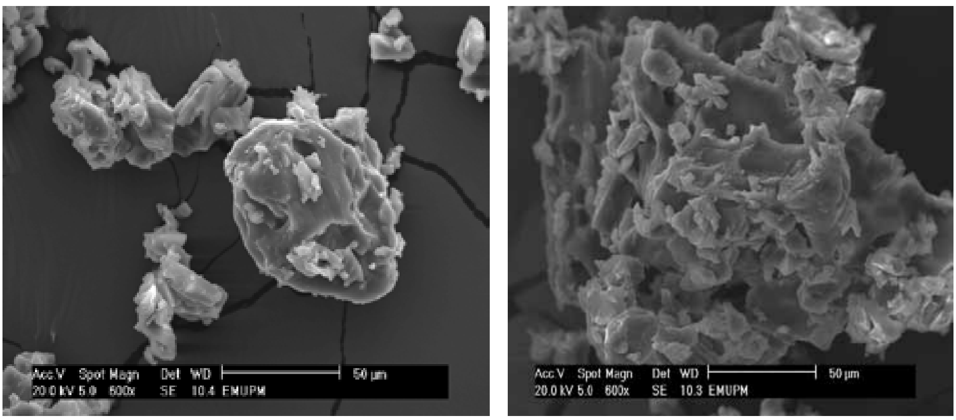

Figure 4. Scanning Electron Microscopy (SEM) of drum dried VitAto™ flour

Conclusion

Most minerals (Ca, Mg, P, S, Na, K and Zn) and vitamin C contents of drum dried VitAto™ flour was higher than hot-air dried VitAto™ flour. Analysis of sugar showed that drum drier flour technique had a higher content of total sugar and reducing sugar than hot air dried flour. The colour parameters showed the L* values for hot-air dried flour were higher than those observed in drum dried flour. Drum dried VitAto™ flour had higher swelling power and solubility than hot air dried VitAto™ flour. Scanning electron microscopy showed the characteristics of granules of both flour are totally different in shapes, size of granules and average size range. This study suggested that drum drier processing technique was better than hot air drier since the physico-chemical characteristics of this end product showed a good value and content.

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Abstrak
Pencirian fiziko-kimia tepung VitAto™ (mineral, vitamin, warna, jumlah gula, gula penurun, jumlah kanji, keterlarutan dan kuasa ketelapan) serta saiz granul tepung daripada dua teknik proses pengeringan (udara panas dan pengeringan dram) telah dikaji. Sampel ubi keledek VitAto™ diperoleh di Malaysia. Kandungan kalsium, magnesium, fosforus, kalium, natrium, sulfur, zink dan vitamin C dalam tepung VitAto™ pengeringan dram adalah lebih tinggi secara signifikan (p <0.05) berbanding dengan tepung udara panas. Teknik pengeringan dram memberikan jumlah kanji (36.55 ± 0.89) dan keterlarutan dan kuasa penyerapan yang tinggi dengan kenaikan nilai suhu. Selain itu, jumlah gula (76.57 ± 0.67) dan gula penurun (25.02 ± 0.09) bagi tepung VitAto™ pengeringan dram juga lebih tinggi berbanding dengan pengeringan panas. Selain itu, analisis pengukuran warna menunjukkan keputusan nilai L* (76.57 ± 0.67) dan b* (52.93 ± 5.17) bagi tepung yang dihasilkan dengan kaedah pengeringan dram mempunyai nilai yang lebih tinggi dan signifikan (p <0.05) berbanding dengan tepung pengeringan udara panas. Analisis mikroskopi pengesan elektron (SEM) menunjukkan teknik pengeringan dram menghasilkan tepung yang mempunyai struktur granul yang lebih besar dan saiz yang tidak sama dengan purata saiz bermula daripada 50 – 200 μm. Ini memberikan alasan bagi nilai keterlarutan yang lebih tinggi bagi tepung yang dihasilkan melalui teknik pengeringan dram. Oleh itu, hasil kajian ini menunjukkan tepung VitAto™ yang dihasilkan daripada teknik pengeringan dram sesuai dipraktikkan sebagai teknik pengeringan dalam industri makanan.