EFFECT OF TEMPERATURE AND SLICE SIZE ON AVOCADO PULP DRYING RATE AND OIL YIELD

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ABSTRACT

The effect of temperature and slice thickness on avocado pulp drying rate and oil yield was determined at 50°C, 60°C and 70°C. Pulp slices of 2mm and 5 mm thick were used. The avocado pulp was found to contain 74-75% (wet basis) water, which makes extraction of oil by both chemical and mechanical means difficult. Experimental results showed that oil yield increased with decreasing moisture content reaching a yield of 61% at 10% moisture content. The rate of drying increased with temperature, but decreased with slice thickness. The drying data obtained agreed well with several thin-layer drying models. The models showed that the characteristic drying constant increased linearly with drying temperature and decreased with slice thickness. The Physico-chemical properties of the obtained oil compared favorably with those obtained from other conventional seed oils.

Keywords: avocado, thin layer, drying, moisture ratio, drying constant

INTRODUCTION

Avocado (*Persea americana*) pulp contain 8-32% oil (Bizimana *et al.,* 1993). The oil is used in food as flavoring agent, cooking oil or salad dressing; in cosmetics as a skin care agent (nourishing and anti-aging) because of its regenerative and moisturizing properties; and as a feedstock for biodiesel production. Avocado oil is one of few vegetable oils not derived from seeds; it is pressed or extracted from the fleshy pulp surrounding the avocado pit.

Tanzania is endowed with diverse climatic zones that support different varieties of avocados, which are mainly consumed locally as fruits. Avocado grows successfully on many types of soil provided they are deep, with good water holding capacity and free draining. Temperatures between 16 and 24°C are good for growing avocados, while the maximum recommended temperature is 33°C (Dorantes *et al.,* 2004). An average avocado tree produces about 80 to 100 kg of avocados annually (Dorantes *et al.,* 2004), while the oil yield is about 2260 L/ha (Tyson *et al.,* 2004).

Some avocados from smallholder farmers in Tanzania and similar least developed countries are spoiled mainly because of poor transport infrastructure to the market coupled with poor storage facilities. Solvent extraction, centrifugation of pulp slurries and mechanical pressing are some of the techniques that are used in processing avocados for their oil. These techniques require disruption of both the oil cells and the finely dispersed oil emulsion in the fruit pulp (Bizimana *et al*., 1993). Affordability of technologies employed is one of the means of reducing spoilage while increasing earnings, thus alleviating poverty.

Avocado oil processing is very much affected by the moisture content in the pulp. Avocadoes contain 65-85% (wet basis) moisture (Undurraga *et al.,* 1987; Kruger *et al.,* 1995; Gomez-Lopez, 2000). This moisture causes formation of paste when the pulp is pressed thus hindering penetration of solvents in solvent extraction process as well as movement of oil in mechanical oil pressing process. Reduction of moisture content is thus important for better oil yield as well as preservation. Moisture content can be reduced through drying which involves simultaneous mass and heat transfer operations accompanied by physical and structural changes. These changes inevitably influence drying characteristics of the materials. Shrinkage is one major physical property change that takes place during drying process. Shrinkage influences bulk density, particle shapes and moisture removal rate.

Variation of the moisture content in the course of drying, M_t, is calculated as

$$M_t = \frac{m_i - m_d}{m_i} x100 \qquad (1)$$

where m_i is the initial mass, m_d is mass of bone dry material.

Successful moisture removal depends upon a slow steady heat supply to ensure that the product is dried from the inside to the outside, without causing surface hardening. Size of pieces, initial moisture content, and the drying method selected all affect the time required to reduce moisture content to the required level (Meisami-asl *et al.,* 2009; Karim, 2010; Ramallo and Mascheroni, 2012).

The rate of drying is important information in finding the time required to attain a targeted moisture level. Conventionally, the drying rate at constant conditions, n, is defined as:

$$n = \frac{m_d}{A}\frac{dx}{dt} = -\frac{m_d}{A}\frac{dx_f}{dt} \qquad (2)$$

where, n ($kg.m^{-2}h^{-1}$) is the rate of water evaporation, A is the evaporation area (may be different from heat transfer area) and m_d is the mass of bone dry solid, x is the dry basis moisture content and x_f is the free moisture. If A is not known, then the drying rate may be expressed in kg water evaporated per hour. A plot of n versus x (or x_f) gives the drying rate curve.

Mathematical models have been used to describe the drying of agricultural produce of which thin-layer drying models are the most common (Mohammadi *et al.,* 2010*;* Radhika *et al.,* 2011, Tahmasebil *et al.,* 2011, Meisami-asl *et al.*, 2009; Hii *et al.,* 2009). The models assume all grains are fully exposed to the drying fluid under constant drying conditions, i.e. at constant fluid temperature and humidity. Thin-layer drying models include, but not limited to, Newton, Henderson and Pabis and Wang and Smith models (Tahmasebil *et al.,* 2011; Hii *et al.,* 2009, Meisami-asl *et al.*, 2009) which are given as:

Newton:

$$MR = e^{-kt} \qquad (3)$$

Hendersen and Pabis:

$$MR = a \cdot e^{-kt} \qquad (4)$$

Wang and Smith:

$$MR = 1 + a \cdot t + b \cdot t^2 \qquad (5)$$

where k is the drying constant(1/s), t is the drying time (s), a and b are constants and MR is the moisture ratio which is also given as:

$$MR = \frac{M_t - M_e}{M_o - M_e} \qquad (6)$$

where M_e is equilibrium moisture content and M_o is the initial moisture content.

The objectives of this work were to determine the effect of drying temperature and avocado pulp slice size on the drying rate and oil yield.

MATERIALS AND METHODS

Three avocado varieties (Ardith, Carlsbad and Hass) were collected from Dar es Salaam markets. Avocado pulp cut into random slice sizes was dried at 105°C where variation of moisture content with drying time was measured. This was followed by oil pressing in order to establish the effect of moisture content on oil yield as well as the total moisture content. The drying was done in Binder heating oven model E28, which has a maximum temperature of 230°C.

Other avocados were then cut longitudinally in quarters and the pulp sliced into 2 mm and 5 mm thick pieces (Figure 1) using a knife and ruler. The slices, about 0.5 kg per batch, were spread (forming a single layer) on mesh trays of Binder incubator model BD53 electric oven with a maximum temperature of 100°C. The trays were inserted in the drying chamber of the oven. The electric oven was operated at pre-set temperatures of 50, 60 and 70°C. Samples were removed from the drying chamber after every one hour and weighed to record moisture loss, until when constant weight was obtained.

Figure 1: *Avocado slices for drying*

RESULTS AND DISCUSSION

1 Moisture Content of Avocado Pulp

Avocado pulp slices dried in an oven at 105°C reached final mass after about four hours. The results show that avocado pulp for Ardith, Carlsbad and Hass cultivars is composed of 73.0%, 74.2% and 74.4% (wet basis) moisture, respectively. This indicates that the three varieties of avocado had marginal difference in moisture content, hence can be treated the same way in drying. These results are similar to those by Undurraga *et al.* (1987), Kruger *et al.* (1995) and Gomez-Lopez (2000). Because of the observed insignificant variation in moisture content of the three cultivars, Hass variety which is most abundant in Tanzania was used further in the study.

1 Effect of moisture content on Oil yield

The oil yield increased with decrease in moisture content as shown in Figure 2. At high moisture content oil pressing was difficult and ended with either a paste or oil emulsion. The figure indicates that the best oil yield is obtained at about 10% moisture content. This yield of about 61% is in agreement with ITDG (1994). Thus the rest of the work focused on effect of temperature and slice size in reducing the moisture content to this level.

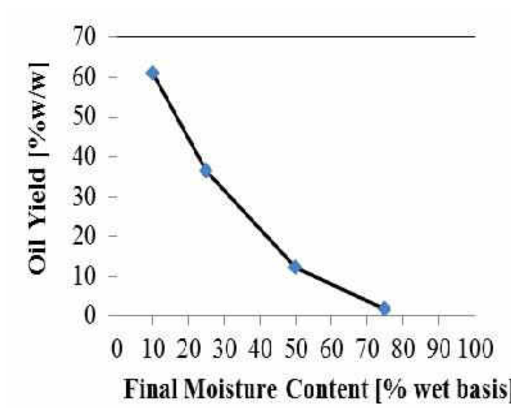

Figure 2: *Variation of oil yield on the moisture content of the pulp*

2 Quality of the crude oil

The oil obtained at 10% moisture was analyzed for some key quality parameters as shown in Table 1. The free fatty acid was calculated in terms of oleic acid because that is the dominant component of avocado oil (Oleata *et al.,* 2007).

The lower the FFA, the more is edibility of the oil and the better the oil as a feedstock for biodiesel production. The obtained values shown in Table 1 are higher than the standard values for edible oil as reported by Woolf *et al.* (2009).

Table 1: Quality of crude Avocado oil

Parameter	Experimental	AOCS (Woolf *et al.*, 2009)
Specific gravity	0.914-0.915	
FFA (% w/w)	0.43-0.89	<0.5
Acid value (% w/w)	0.86-1.12	<1.0
Colour	Green to yellow	Green to yellow
Moisture content	0.2-0.24	<0.1
Viscosity (mm^2/s)	16.4	
Unsaponifiable matter (%)	0.32-0.88	<1
Cloud Point (^oC)	7-9.8	

The same FFA level is not suitable for biodiesel production through homogeneous catalysis as per ASTM D6751 standard. Hence the oil needs to be refined for edible as well as biodiesel production purposes. The acid value, which is another measure of edible oil quality is not satisfactory, thus oil refining is also called for. Unsaponifiables are components of an oily (oil, fat, wax) mixture that fail to form soaps when blended with lye. These constituents are an important consideration when selecting oil mixtures for the manufacture of soaps because they may have properties such as moisturization, conditioning, vitamins, texture, etc.

Cloud point is the temperature at which the oil will start forming solid particles, which might clog fuel filters if used as a biofuel in engines. The results reported here shows that avocado oil cannot be used as a fuel in low temperature areas without further processing.

3 Effect of Temperature on Moisture Reduction

The drying rates for the three oven temperatures shown in Figure 3 indicate that the drying process was in the falling rate period. The figure shows that for the same slice thickness the drying rate increases with temperature because higher drying temperature result into larger temperature gradient giving higher heat transfer which drives the moisture out of the avocados. For the same drying temperature thicker slices give less drying rate. This is a result of less heat to drive the moisture out, which is caused by higher heat resistance (smaller temperature gradient).

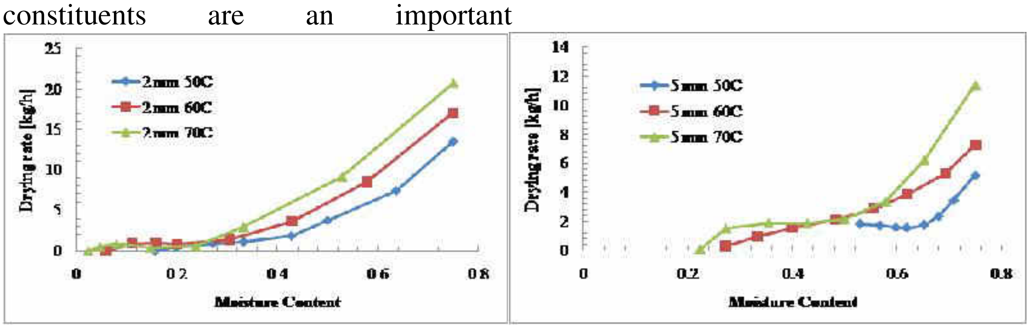

Figure 3: *Variation of rate of drying of avocado pulp with temperature and slice sizes*

It is also evident from Figure 4 that the higher the temperature the faster the moisture removal. Higher temperatures provide large temperature gradient between the surface of pulp and the surroundings thus leading into higher mass transfer – removal of the moisture. At the beginning of the drying process weight loss was faster as a result of large mass transfer due to large concentration difference between the surrounding air and the moisture in the avocado pulp. As time goes, more moisture is transferred from the avocado to the surrounding air. This decreases free moisture in the avocado and the concentration difference thus reducing moisture removal as observed by the flattening trend. The drying is then controlled by bound moisture, which is difficult to remove from the pulp than free moisture (water that is in excess of equilibrium moisture content).

4 Effect of Pulp Slice Size on Moisture Reduction

Figure 4(b) shows that the 5 mm thick slices attained a moisture content of 10% (MR=0.13), which is desired for good oil processing after 7.0 and 5.9 hours for drying temperature of 60°C and 70°C, respectively. With low temperature of 50°C it was not possible to achieve the targeted moisture content even after 7 hours, thus longer drying period is necessary. Figure 4(a) shows that the 2 mm slices attained the same moisture content after 5, 3.3 and 2.5 hours for drying at 50°C, 60°C and 70°C, respectively. It is evident from Figures 3 and 4 that at a constant temperature, the thinner the slices the faster is the drying process. This can be attributed to increase in surface area exposed to drying and shorter distance for the moisture to travel from the inner cells to the surface, which gives large temperature gradient as well as concentration gradient for the same starting conditions. The dependence of drying rate on the slice thickness is similar to the work of Meisami-asl *et al.* (2009). It is thus desirable to have as thin slices as possible for faster moisture reduction from the avocados.

5 Thin-layer drying models

The results shown in Figure 4 agree well with the three thin-layer drying models shown in Table 2. However, Henderson and Pabis model seems to represent the experimental data better than the other two. The model fitting shows slight temperature and slice size sensitivity.

Table 2 shows that drying constant k increases with temperature indicating that the higher the temperature the faster the drying process as expected of a temperature assisted mass transfer. The variation of drying constant with temperature summarized in Table 3 is linear. This is in agreement with Chinenye (2009), Senadeera (2008) and Cano-Chauca *et al.* (2004). The latter, however, reported a decrease in drying constant with increasing temperature. Effect of drying temperature on the drying rate is also similar to the results of Meissami-asl *et al.* (2009). It is thus evident that the higher the temperature the shorter the drying time for achieving the targeted moisture content.

The thin layer drying models also show that the drying constants for 2 mm thick slices are larger than the corresponding values for 5 mm slices, which confirms that the smaller the particle size the faster is the drying process.

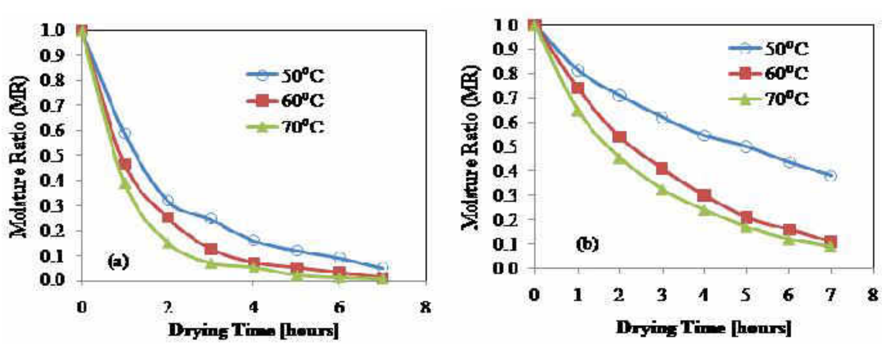

Figure 4: *Variation of moisture ratio in avocado pulp slices with time (a) 2 mm (b) 5 mm*

CONCLUSIONS

From the results of this work, the following conclusions are made:

- Three avocado cultivars contain almost the same amount of moisture, 74-75%, which makes recovery of oil from the pulp by both chemical and mechanical means difficult. The time required to reduce moisture to around 10% decreases with slice thickness and increasing drying temperature.
- The drying constant increases with decreasing slice thickness. Thin avocado slices expose more surface area for drying and give larger temperature as well as mass gradients, thus resulting in faster moisture removal (drying) process. Based on the results the smaller the size of the slices (here 2mm) the faster is the drying process.

Hendersen and Pabis thin layer drying model fitted better in the experimental data than Newton and Wang and Smith models.

Table 2: Variation of Drying constant with temperature and slice thickness

Temperature	Model	Thickness	Polynomial Coefficients		Rate Constant	Regression coefficient
(□C)		(mm)	a	b	k	R^2
50	Newton	2			-0.431	0.9790
		5			-0.143	0.9826
	Henderson & Pabis	2	0.8625		-0.402	0.9866
		5	0.948		-0.132	0.9919
	Wang & Smith	2	-0.351	0.0322		0.9543
		5	-0.1562	0.0101		0.9892
60	Newton	2			-0.653	0.9859
		5			-0.309	0.9988
	Henderson & Pabis	2	0.895		-0.611	0.9877
		5	1.0174		-0.313	0.9990
	Wang & Smith	2	-0.4095	0.0401		0.9265
		5	-0.2522	0.183		0.9997
70	Newton	2			-0.779	0.9865
		5			-0.354	0.9957
	Henderson & Pabis	2	0.8033		-0.735	0.9916
		5	0.9336		-0.34	0.9980
	Wang & Smith	2	-0.4474	0.0458		0.8785
		5	-0.299	0.0249		0.9812

Table 3: Variation of drying constant with temperature (°C) for different slice thicknesses

Pulp Thickness	Model	Equation for k	R^2
2 mm	Newton	k = -0.0174T + 0.4230	0.9753
	Henderson & Pabis	k = -0.0167T + 0.4163	0.9787
5 mm	Newton	k = -0.0106T + 0.3643	0.9012
	Henderson & Pabis	k = -0.0104T + 0.3623	0.8455

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