Optimum processing parameters for coconut oil expression

Kehinde Adedeji Adekola*

(*Department of Agricultural Engineering, College of Biological and Agricultural Engineering, Jilin University (Nanling Campus), Changchun, P.R. China*)

Abstract: In order to obtain the highest process efficiency for oil production, considerations should be given to the determination of the optimum processing parameters. Coconut oil has many domestic, industrial, food, medicinal and cosmetics usages. Coconut trees which produce coconut fruits are widely available in tropical climates all over the world and as such its uses are still been exploited. From literature reviews, studies into optimum processing parameters for many oil seeds have been reported, however none exists for coconut oil processing parameters. Therefore, this study focused on the determination of optimum processing parameters for coconut oil production. Experimental studies carried out in this study considered the following processing parameters: post heating moisture content, applied pressure, pressure duration, heating time and temperature to which the dried coconut meat samples were subjected using hydraulic uniaxial compression method. Optimum values for these parameters were determined and reported. The highest coconut oil yield obtained was 51.9% at optimum condition. This yield corresponds to an expression efficiency of 81.2% of the total coconut oil content, which represented 63.9% by weight of the copra (dried coconut flesh). The highest oil yield was obtained at an expression pressure of 25 MPa when samples were conditioned to an initial moisture content of 11.3% (w. b.) and heated at 120℃ for 15 min to obtain a post heating moisture of 7.13% (w. b.). Increases in oil yield were recorded for increases in applied pressure but this tended to level off between pressures of 20 MPa and 25 MPa. At all levels of pressure used, applied pressure duration of 10 min was found to be optimum for high oil yield. The specific gravity of coconut oil produced in this study was found to be 0.95 and the viscosity was 960 pa.s. for the measured temperature of 30℃ and refractive index of 1.45. The saponification value, iodine value and free fatty acid values measured were 259, 9.6 and 27 respectively. The results obtained are in conformity with the oil quality standard as specified by AOAC. The findings and results from this study will be of immense benefits to researchers, processors, machine manufacturers and entrepreneur involved in coconut oil production.

Keywords: coconut oil, processing parameters, oil yield, expression efficiency, optimum

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1 Introduction

The coconut fruit is drupe with a thin epicarp overlying a thick fibrous mesocarp (Salunke and Desai, 1986). The main food uses of coconut oil are in margarine, confectionery and baked products. The non-food uses are as raw material in the manufacture of toilet soap, candles, cosmetics, hydraulic brake fluids and other industrial products.

The local method of oil expression from coconut involves shredding of the coconut meat before it is placed in water, squeezed and mixed by hand. The mixture is then boiled until all the water is evaporated leaving oil and pulp. Straining and hand squeezing are used to separate the oil from the pulp. This local method is slow, inefficient and labor intensive (Adekola, 1991). In order to produce good quality oil on a large scale, a systematic investigation and an analysis of the processes involved are necessary.

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***Corresponding author: Kehinde Adedeji Adekola,** Department of Agricultural Engineering, College of Biological and Agricultural Engineering, Jilin University (Nanling Campus), 130025, Changchun, P.R. China. Email: profkola@sina.com.

There are three steps for full expression of vegetable oil from either oil seeds or nuts. The first was to roll decorticated oil seed thoroughly to rupture completely the greatest number of oil cells and to produce a homogenous flake. The second step was a leisurely complete cooking to ensure no scorching or burning as well as provide a minimum amount of agitation to rupture the remaining unruptured oil cells and to coagulate the protein in the screw press operation (Adekola, 1991). Processing factors that affect oil expression from seeds and nuts are similar but differ only in degree from one to another.

Pominski et al. (1970) reported that the amount of oil expressed from groundnut tended to level off after 3 min of pressing at a pressure of 13.8 MPa. Moisture content after heating, the amount of heat and pressure were found to be the most significant factors affecting the yield of oil expressed mechanically from conophornut (Ajibola and Fasina, 1990). Ajibola et al. (1990) found that the highest yield of about 41% were obtained from melon seed at an expression pressure of 25 MPa when samples were conditioned to initial moisture contents of 9% and 12% w.b. before heating. A moisture reduction of 5% in samples was obtained after heating.

It has been reported that the oil content for white coconut meat is between 40% and 45% but when dried (copra) contains between 63% to 65% oil (Khan and Hanna, 1983). From extensive literature survey conducted, no detailed study is known to have been undertaken on processing factors as related to oil yield from coconut. This prompted the present work to study the effects of some processing parameters on coconut oil expression.

2 Experimental procedure

2.1 Laboratory press

The uniaxial hydraulic compression press is made up of a rectangular base plate, a mild steel pressing cylinder with diameter of 11.4 cm and a mild steel tapered plunger. The cylinder was securely welded to the mild steel base plate. A 60 ton capacity hydraulic press forces the plunger down squeezing the sample in the cylinder and pressed oil emerges through oil holes of 3 mm in diameter. The oil was collected in a measuring cylinder, which measures the volume of oil expressed over a selected time interval through the funnel.

A metal disc of 11.3 cm diameter and a thickness of 1.0 cm was placed in the barrel on the sample to be pressed so as to distribute the pressure from the press evenly over the sample.

2.2 Preparation of sample

Deshelled coconut fruits used for this study were obtained from local ‘Oje’ market in the North East, Ibadan, the capital city of Oyo State of Nigeria. The nuts were shelled manually by hitting them on a slopping concrete floor to allow the coconut water to drain out and the white meat gouged out of the shell using a knife.

The white meats were then chopped into smaller pieces. The chopped coconut meats were dried using an oven set at temperature of 110℃ for 6 h. The copra was then milled using a laboratory grinding burr mill. The geometric mean diameter and geometric standard deviation of the milled sample were 1.43 and 1.42 mm respectively. These were determined using American Society of Agricultural Engineers (ASAE) Standard S319.2.

Samples of milled copra were then conditioned to various moisture contents considered in this study. The levels of moisture studied were 5%, 8% and 11% (w.b.). Known amount of water (10–25 mL) were sprayed evenly on the samples to desired levels. The mixture was then placed in a refrigerator and allowed to equilibrate for a minimum of 72 h. The actual moisture content was confirmed after conditioning using electronic moisture meter model EMM-67.

The condition samples were then heated by spreading a thin layer of 80 g in 15 cm×10 cm×2 cm tray and placed in a vacuum oven model KJ17C-H set at different heating temperature and time combinations considered in this study. The three levels of heating temperatures used were 60℃, 90℃ and 120℃ while the three levels of heating times were 5, 15 and 25 min.

The heated samples were then wrapped tightly in cheese cloth (“Teru” type) of (0.21 mm) thickness and porosity (0.15 mm), introduced into the pressing cylinder and pressed. The cloth was able to withstand the highest pressure of 25 MPa. The four levels of pressure considered were 10, 15, 20 and 25 MPa while the pressing durations were 2, 5, 8 and 10 min. The levels of processing factors in this work were selected based on the result of preliminary studies carried out.

The amount of oil expressed after 10 min of pressure application was determined by subtracting the weight of pressed cake from that of pre-pressed material. Oil yield was based on the weight of the pre-pressed sample. The moisture content of oil was taken as the moisture content of already heated sample just before oil press. A total of 216 experimental runs were conducted with at least two replicates per run (Ajibola and Fasina, 1990). Expression efficiency is defined as the ratio of oil yield to oil content of copra for this work.

2.3 Analytical procedure

The oil content of milled copra was determined using Soxhlet extraction apparatus. This is in accordance with the Association of Analytical Chemists direct gravimetric method of Soxhlet extraction (AOAC, 1984). Likewise, free fatty acids, iodine and saponification values of the oil were also determined using the American Oil Chemists Society (AOCS, 1984) method. The moisture content of samples were determined by vacuum oven drying a thin layer of 100g of milled samples at 130℃ for 6h as recommended for oil seeds (Young *et al*,1982).

The milled particles size of samples were determined using ASAE standard S319.2 (ASAE, 1993). The index of refraction of oil was determined by means of Baroid concentric desk rheometer (AOAC, 1984). The relative density of the oil was determined using the standard density bottle method (Adekola, 1991).

3 Results and discussion

3.1 Effect of processing factors on oil yield

Experimental results revealed that oil yield increases with increases in applied pressure. Statistically, with the correlation coefficient of 0.986 at probability level of 0.01 significant increases in oil yield were noticed for pressure increases between 10 and 20 MPa. The reduced oil yield from similar conditioned samples pressures increased from 20 to 25 MPa. This may be due to the blocking of oil path between some inter-kernel voids because of compaction of particles.

On the effects of pressure application duration on oil yield, at the end of 10 min of pressure application, all available oil contained in the sample had been expressed. This suggested that a pressing time of 10 min is optimum pressure duration based on the multiple replicates of experiments carried out.

Table 1 showed the relationship between initial moisture content and moisture content after heating. From the table and at various combinations of heating time and temperature considered, moisture loss depended on the initial moisture content in each case.

Table 1 Effect of initial moisture contents, heating temperature and heating time on moisture contents after heating

Initial moisture content, % (w.b.)	Heating temperature, ℃	Heating time, min		
		5	15	25
5.02	60	5.00	4.95	3.70
	90	3.52	3.23	1.95
	120	2.01	1.34	0.32
8.14	60	7.94	7.83	5.89
	90	7.11	6.34	4.46
	120	5.96	4.20	2.81
11.3	60	11.0	9.84	8.12
	90	10.8	9.32	7.03
	120	10.0	7.13	5.35

Note: The values reported in the above table are the means of replicates.

For all levels of pressure application and initial moisture content of 5.02% (w.b.), the oil yield decreases with decrease in post heating moisture content, while the oil yield increases with reduction in post heating moisture content. This trend is similar for initial moisture content of 8.14% (w.b.), however, at 11.3% (w.b.) moisture content, oil yield increases with slight moisture loss. This suggests that post-heating moisture content is an important indicator in determining oil yield from copra.

From Table 2, oil yield increases with increases in heating temperatures for samples conditioned to 8.14% and 11.3% (w.b.) moisture contents at all pressures considered in this study. This can be attributed to effect of heat on viscosity of oil and thereby increases the flow of oil. However, at 5.02% (w.b.) moisture content, the reverse was the case. Oil yield reduces with increases in temperature of heating. This development might suggests that there are limits under which viscosity theory proposed above hold.

Table 2 Effects of initial moisture content, heating temperature and heating time on oil yield at one of the pressure considered (10 MPa)

Initial moisture content, % (w.b.)	Heating temperature, ℃	Heating time, min			Unheated sample
		5	15	25	
5.02	60	42.8	42.5	42.0	40.2
	90	41.0	40.2	38.5	
	120	37.8	37.8	35.5	
8.14	60	38.0	38.5	38.7	37.0
	90	39.0	39.0	39.6	
	120	38.9	40.0	40.8	
11.3	60	34.8	35.8	37.2	29.4
	90	36.5	37.1	38.6	
	120	38.2	42.3	44.0	

Note: The values reported in the above table are the means of replicates.

Experimental results as shown by Tables 2 and 3, revealed that a heating time of 15 min represented an optimum heating time for maximum oil yield from coconut. At heating times longer that 15 min, especially at heating temperature of 120℃ and heating time of 15 and 25 min, oil yield losses of about 1.75% and 12.3% were recorded for moisture contents of 8.14% and 11.3% (w.b.) respectively. The results obtained are unique for coconut oil production and different from other results obtained by other researchers for other oilseeds as reported earlier. No previous similar work for coconut oil expression has been reported.

Table 3 Effects of initial moisture content, heating temperature and heating time on oil yield at one of the pressure considered (25 MPa)

Initial moisture content, % (w.b.)	Heating temperature, ℃	Heating time, min			Unheated sample
		5	15	25	
5.02	60	47.0	46.8	46.2	44.2
	90	45.1	44.2	42.3	
	120	41.6	41.6	39.1	
8.14	60	49.4	51.8	49.2	47.9
	90	50.7	52.7	47.1	
	120	50.6	54.0	43.8	
11.3	60	45.2	46.8	41.2	38.2
	90	47.4	48.2	39.9	
	120	49.7	50.3	38.0	

Note: The values reported in the above table are the means of replicates.

3.2 Effect of processing conditions on oil quality

Processing conditions considered in this study did not have noticeable effect on color, specific gravity, refractive index and viscosity of expressed oil. Table 4 shows average values, measured range, literature range and standard deviations of these physical properties. The measured values correspond favorable with average values quoted in the cited references.

Table 4 Some physical and mechanical properties of coconut oil

Properties	Literature review	Experiment measured (average)	Deviation from literature	Experiment measured (range)
Refractive index	1.4481-1.1197	1.4488	0.001	1.4480-1.04496
Relative index	0.925-0.935	0.950	0.002	0.932-0.968
Viscosity at 30℃	0.9781-0.9684	0.9632	0.001	0.9628-0.9636
FFA value	21-25	27	0.001	24-30
Iodine value	8-10	9.6	0.001	9.4-9.8
Saponification value	246-268	259	0.003	250-268

4 Conclusions

Processing factors in oil expression dictate to a very large extent the quality and quantity of oil expressed. Based on the multiple regression analysis carried out on the experimental results, an optimum set of pressing conditions for maximum oil yield from coconut were determined and accordingly recommended for coconut oil processors. These conditions are applied pressure of 25 MPa, pressing duration of 10 min, heating temperature of 120℃, heating time of 15 min and initial moisture content of 8.14% (w.b.).

Therefore, it can be concluded that to justify investment in machinery and system procurement in terms of return from oil yield, adherence to these processing factors is essential.

An efficient drying technique is also essential for the production of high quality copra for oil expression, hence there is the need for the use of tested dryers.

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