Characterization of coconut oil in different varieties in Sri Lanka

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Identification and characterization of morphological/physical properties of different varieties of coconut are very important in breeding programs and the quality parameters of oil, such as degree of saturation, free fatty acids and average molecular weight of fatty acids are vital for selecting a type of oil for human consumption. The aim of the study was to test the effect of variety on oil concentration and oil quality properties of thirteen different coconut varieties (San Raman, Nawasi Thembili, Ran Thembili, Dwarf Yellow, Dwarf Green, Dwarf Brown, King Coconut, CRIC 65, Dikiri, Kapruwana, CRIC 60, Sri Lanka Tall and Nawasi Pol) grown in Sri Lanka and to evaluate morphological/physical properties in the varieties. The degree of saturation and average molecular weight of the fatty acids were studied using the parameters of iodine and saponification values respectively. Furthermore, free fatty acids and peroxide value of oils were also studied. The evaluation of morphological/ physical characters revealed that Dikiri and San Raman were the best varieties for oil extraction. The lowest performances were observed in Nawasi Thembili, Dwarf Green, King Coconut and CRIC 60 varieties. Further, Ran Thembili, Dwarf Yellow, Dwarf Brown, CRIC 65, Kapruwana and Sri Lanka Tall varieties showed the intermediate characters. Among the tested varieties, the highest saturated fatty acid contents were observed in Nawasi Thembili and the highest unsaturated contents were observed in Dwarf Green, Dwarf Yellow and Dwarf Brown varieties. The highest average molecular as indicated by the highest saponification value was shown by Ran Thembili and Dikiri varieties, while Nawasi Thembili and Dwarf Yellow were the lowest. Ran Thembili variety showed the maximum initial free fatty acids content and the lowest content was observed in the Sri Lanka Tall variety. Autoxidation was not observed in any sample immediately after oil extraction. Dwarf Green, Dikiri and Sri Lanka Tall varieties showed the highest moisture contents and Nawasi Thembili, the lowest. It is concluded from the results that Dwarf Green, Dwarf Yellow, San Raman and Nawasi Thembili are the best varieties for quality oil extraction for human consumption.

Keywords: Autoxidation, average molecular weight, coconut oil, degree of saturation, fatty acids, free fatty acids, peroxide value

The coconut palm (*Cocos nucifera L.)* is one of the major plantation crops cultivated in the tropics for its multiple uses. It belongs to family Arecaceae, which contains the most versatile and common palm species found in the humid tropical regions of the world. The Philippines are the world leader in coconut production followed by Indonesia and India (wikipedia.org/wiki/Coconut, 2010).

Coconut is also the most widely grown plantation crop occupying 21% of the total land under agriculture in Sri Lanka (Fernando et al. 1995) and is one of the three major plantation crops on the island. At present, the total land area utilized in the plantation sector is about 750,000 hectares giving direct and indirect employment opportunities for about 1.5 million people in the country. Some 394,836 hectares are covered by coconut plantations according to the Department of Census and Statistics of Sri Lanka (2009), which is second only to the land area under rice cultivation (Statistical Pocket Book of Ministry of Plantation Industry 2007).

Sri Lanka ranks seventh place in the world coconut market producing 954,000 tones from 2,869 million nuts. It contributes about 2% to the country's earnings which is generally around Rs. 24,069 million. The significant feature of the coconut industry is that over 65% of the production (2,456 million nuts) is used for domestic consumption. The balance 35% is used as copra (117 million kilo grams), coconut oil (76 million kilo grams), desiccated coconut (43 million kilo grams) and raw materials for a large number of agro-based industries (Census and Statistics 2007).

Coconut oil occupies an important position in the international vegetable oil

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market and it has a long history for providing several applications for human consumption in daily life. It is used in foods (e.g. cooking oil), cosmetics (e.g. spa oil) and industries (e.g. lubricants) (Jayadas and Nair 2006; 873-878). In addition to its commercial value as an oil crop for generating foreign exchange, coconut also plays a major role in the Sri Lankan diet and social life.

The coconut oil is the major kernel product of coconut in Sri Lanka, next to desiccated coconut. The national requirement in the past was about 3 bottles of coconut oil per head per annum, which can be obtained from about 20 coconut nuts. During 1989 to 2004, the amount of coconut oil used in Sri Lanka varied from 26,105 MT to 82,613 MT with a mean value of 46,802 MT. Accordingly, the domestic consumption of coconut oil per head per year has varied from 2.06 bottles (1.34 Kg) to 6.60 bottles (4.29Kg) in 2003 with a mean of 3.94 bottles (2.56Kg) (Census and statistics 2007).

Coconut oil consists of about 90% saturated fat. The oil contains predominantly medium chain trigliserides, with roughly 92% saturated fatty acids, 6% monounsaturated fatty acids, and 2% polyunsaturated fatty acids. The saturated fatty acids of coconut oil consist primarily of 44.6% lauric acid, 16.8% myristic acid 8.2% palmitic acid and 8% caprylic acid; although it contains a total of seven different saturated fatty acids. Its only monounsaturated fatty acid is oleic acid while its only polyunsaturated fatty acid is linolenic acid. Among the most stable of all oils, coconut oil is slow to oxidize and thus resistant to rancidity, lasting up to two years due to its high saturated fat content. In order to extend shelf life, it is best stored in solid form (i.e. below 24.5°C [76°F]) (wikipedia.org/ wiki/Coconut_oil 2010).

The health benefits of coconut oil include hair care, skin care, stress relief, maintaining cholesterol levels, weight loss, increased immunity, proper digestion and metabolism, relief from kidney problems, heart diseases, high blood pressure, diabetes, HIV and cancer, dental care, and bone strength (www.organicfacts.net/ organic-oils/organic-coconut-oil/health-benefits-of-coconut-oil.html, 2010). These benefits of coconut oil can be attributed to the presence of lauric acid, capric acid and caprylic acid, and their properties such as antimicrobial, antioxidant, antifungal, antibacterial, soothing, etc. (www.organicfacts.net /organic-oils/organic-coconut-oil/health-benefits-of-coconut-oil.html, 2010).

However, the content of the above health beneficial fatty acids could be variable in different varieties grown in Sri Lanka. No systematic studies have been carried out to test the quality parameters of coconut oil extracted from different varieties grown in Sri Lanka in relation to human health. Further, estimation of degree of unsaturation will reveal the resistance to fatty acid rancidity and cooking quality of coconut oil from different varieties.

Therefore the study was conceived with the following objectives.

1. Evaluation of the physical & morphological characters that affect oil concentration.
2. Characterization of the quality of coconut oil in different varieties.

Materials and methods

Sampling

Samples were collected from palms grown under the same ecological conditions on the Coconut Research Institute premises (Low Country Intermediate Zone - IL1a). Nuts were taken from randomly selected palms and all the collected nuts were at the same maturity level, i.e. 12 months old. Nuts were thereafter stored for 21 days on the floor inside the storage building. San Raman (SR), Nawasi Thembili (NT), Ran Thembili (RT), Dwarf Yellow (DY), Dwarf Green (DG), Dwarf Brown (DB), King Coconut (KC), CRIC 65 (DT), Dikiri (DK), Kapruwana (KP), CRIC 60 (TT), Sri Lanka Tall (SLT) and Nawasi Pol (NP) varieties were selected for the experiment.

Oil extraction

Several methods were used to extract coconut oil. Most of chemical properties of coconut oil (Iodine value, Saponification value, etc.) and fatty acid profile do not change with the method of oil extraction. Therefore, coconut oil from different varieties for the experiment was extracted according to the household method of oil extraction; i.e. one of the wet processes. For the determination of total oil content of the kernel, the oil was extracted by the solvent extraction method.

Household method

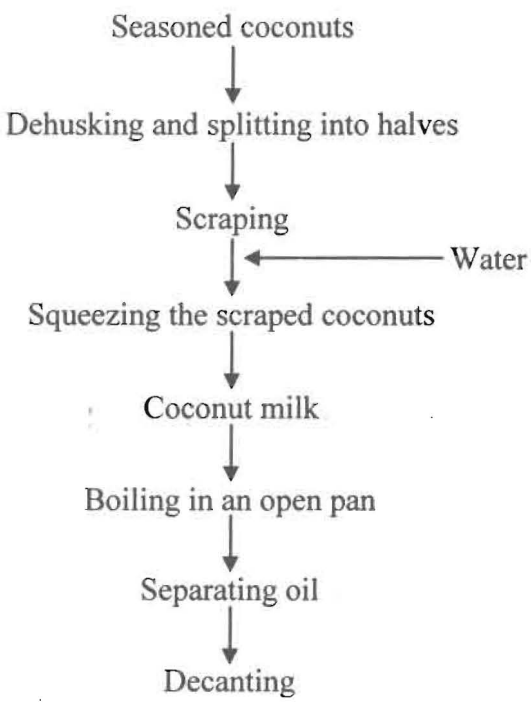

Figure 1: Household method of coconut oil extraction

Seasoned coconuts were dehusked and split into halves with a knife. The kernel was scraped and the gratings were pressed three times by hand with addition of water. The extracted coconut milk then boiled in an open pan as used in the domestic process to yield oil and oily residue. This process took around 2-2 ½ hours to separate oil from coconut milk. The oil is then recovered by decanting. The following process (Figure 1) indicates the household method of oil extraction.

The weight of whole and dehusked nuts was measured with an electrical top loading balance while the process of oil extraction was ongoing. The circumference of the dehusked nut was measured using a tape and the thickness of the kernel was measured with a Varner caliper.

Solvent extraction method

The kernel of the nut was separated from the coconut shell and kept in the oven for 7-8 hours at around 70^0C. The dried kernel was ground into a powder and a paper thimble was filled with a weighed amount of kernel powder. Then, the thimble was placed in the soxlet apparatus and run for eight hours using petroleum ether as the solvent. Meanwhile, the coconut kernel powder was ground once, after four hours, using a mortar and pestle. Thereafter, petroleum ether was evaporated using a rotor evaporator and the weight of the extracted oil was measured. The oil content was reported on both dry and wet bases.

Storing

The coconut oil samples were stored in cleaned bottles in a deep freezer. These bottles were closed properly using a lid and when using, the samples for use were thawed using hot water.

Evaluation of quality of coconut oil

In this study Iodine value, Saponification value, Free Fatty Acids and Peroxide values were determined as quality parameters of the coconut oil samples. The peroxide value was determined according to the AOAC (1990; 801-805) method and other chemical properties were determined according to the Sri Lanka Standard specification (2000) for coconut oil.

Results and discussion

Morphological/ physical properties of coconut from different varieties

Weight of nut

The variations of whole nut and dehusked nut weight of the selected thirteen varieties showed very significant variability of nut weight both with husk ($P<0.0001$) and without husk ($P<0.0001$). The highest weight for both parameters was obtained from Dwarf Yellow and King Coconut varieties whilst, Dwarf Green showed the significantly lowest weight among the varieties. The highest husk mass was produced by the Dwarf Yellow and Dikiri varieties.

The high mass of husk led to generation of small sized peeled nuts. Therefore, it is a disadvantage in coconut breeding. In contrast, for the production of coir fiber the high husk mass is very important. The Yellow Dwarf variety gave the highest weight of coconut with and without husk as well and the highest husk mass. This variety is therefore important to incorporate those characters to the progeny in coconut breeding programs.

Variations of circumference of the dehusked coconut

The variations of the circumference of dehusked coconut were studied and the results are shown in Figure 3. Mean comparison test revealed that the Dwarf Yellow variety indicated the significantly ($P<0.0001$) highest circumference followed by San Raman and Dikiri respectively. The Dwarf Green variety showed the significantly lowest circumference among selected varieties. However, there was no significant difference among the group of San Raman, Dikiri and Sri Lanka Tall varieties.

High circumference is very important as an indicator of large size dehusked nuts. According to the results, two indigenous varieties (Dwarf Yellow and Dikiri) and the exotic variety (San Raman), selected for the experiment, showed the highest values. However, two selected improved cultivars (CRIC 65 and Kapruwana) showed intermediate sized nuts while the oldest improved cultivar of Sri Lanka (CRIC 60) had a comparatively low circumference. Consequently, it is prudent to use varieties with high dehusked nut circumference in coconut breeding programs to obtain large size nuts (Liyanage 1982).

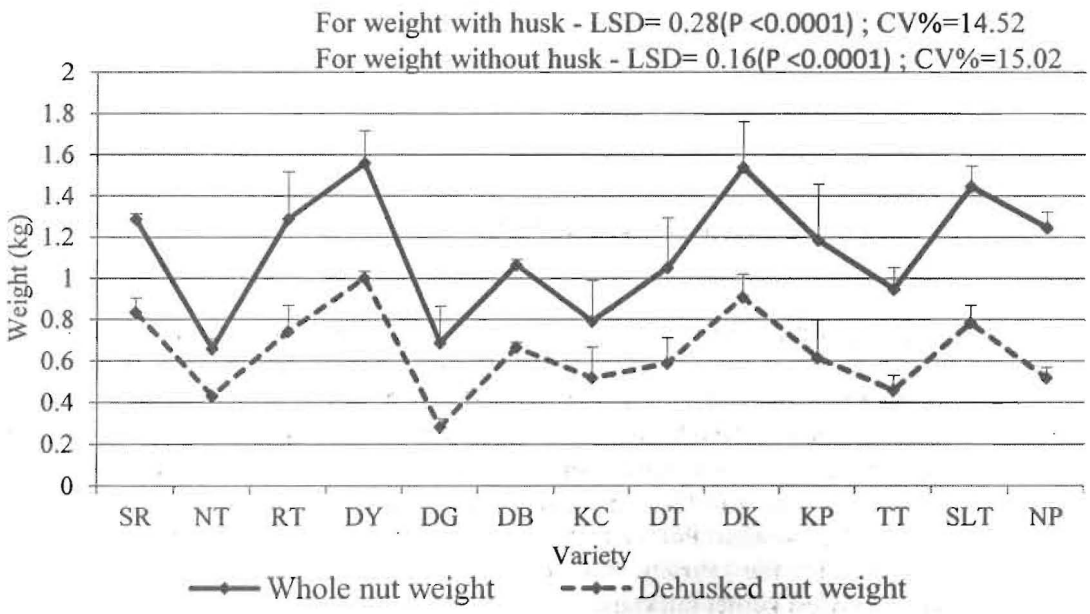

Figure 2: The variations of nut weight with and without husk

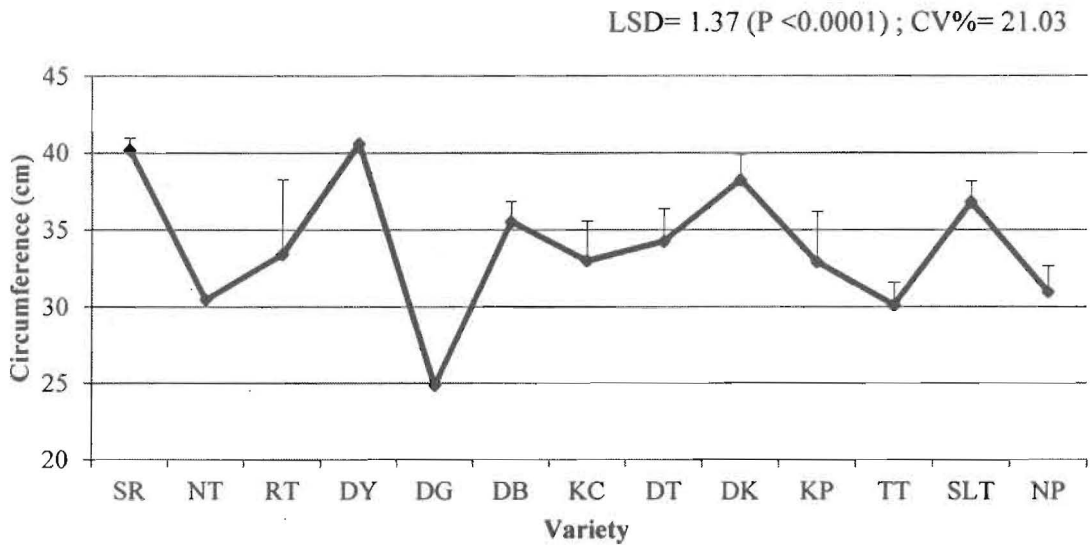

Figure 3: Variations of circumference of the peeled coconut

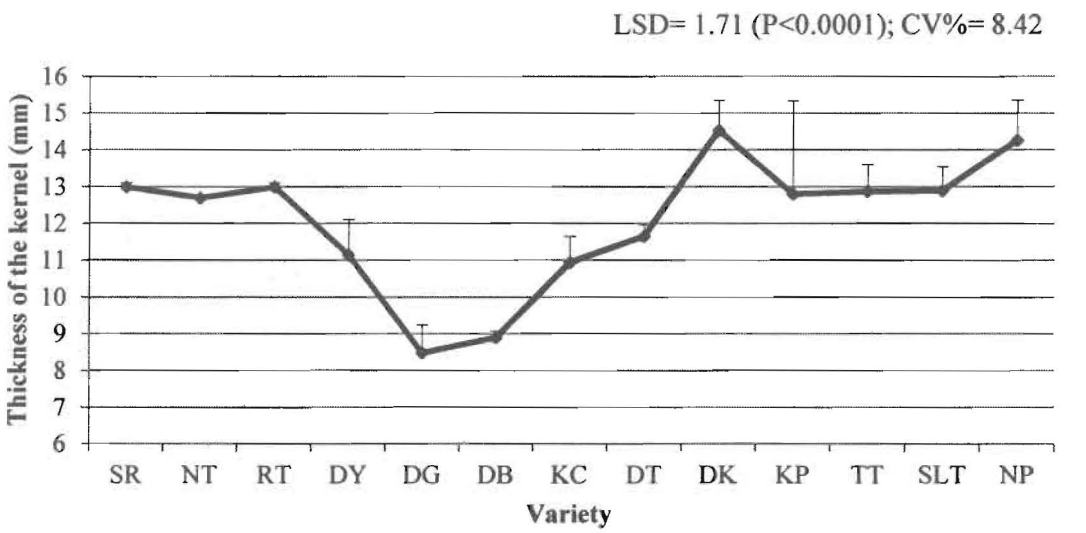

Figure 4: The variations of kernel thickness of different varieties

Variations in thickness kernel

Variation of kernel thicknesses of the selected varieties was significant (P<0.0001) (Figure 4). Dikiri coconut exhibited the significantly highest kernel thickness of the selected varieties followed by Nawasi Pol and Ran Thambili. Meanwhile, the variety Green Dwarf showed the lowest kernel thickness.

Coconuts with high kernel thickness had comparatively higher copra yield. Therefore, Dikiri, Nawasi Pol and Ran Thambili varieties can be used to produce copra. The improved cultivars, CRIC 65 and Kapruwana showed intermediate thickness which was greater than CRIC 60. The mean kernel thickness of all the coconut varieties was 12.1 mm.

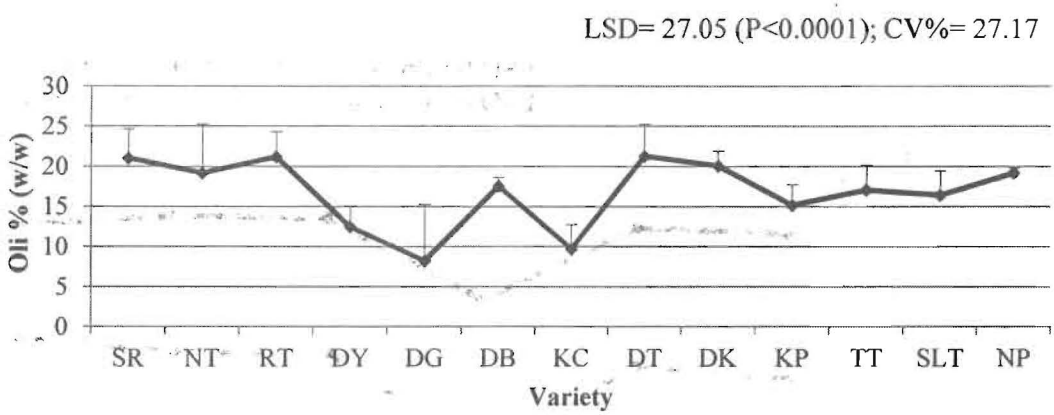

Figure 5: Extracted oil amount from household method

Variation of extracted oil content

The oil content of coconuts collected from the 13 varieties was measured by two oil extraction methods; the household method (a wet process) and the solvent extraction method. The percent oil obtained from the household solvent extraction methods are shown in Figures 5 and 6 respectively.

The varietal variation in oil content measured by the household method is significant. Significantly highest oil contents from the household method were obtained from San Raman and Dikiri varieties. These varieties had the highest thickness of the kernel and the circumference. Dwarf Green and King Coconut gave the significantly lowest contents of oil.

The oil percentages by the solvent extraction method were calculated on both wet and dry kernel weight bases and the results are shown in Figure 6. On the wet kernel weight basis, the extracted oil percentages in the varieties were significant (P= 0.024). The extracted oil percentages on the dry kernel weight basis were not significant (P= 0.1323). Overall results suggested that the kernel has a constant percentage of oil without varietal variation. However, due to the changes of moisture content of the kernel, the oil percentages on the wet kernel weight basis may differ among varieties.

A bunch of Dikiri coconut contains both normal and abnormal coconuts. For oil extraction by the household method the normal coconuts from Dikiri palms were used and the abnormal coconuts were taken to extract oil by the solvent extraction method. The abnormal type of Dikiri coconut has a higher economic value than the normal nuts because it is used in the production of confectionaries. When the solvent extraction method is used the lowest amount of oil was obtained from the abnormal coconuts of the Dikiri variety. The normal nut of Dikiri is a good source for the production of oil by the household method since it gave around 100ml of oil per nut.

In the household extraction method, the Green Dwarf variety gave a very small amount of oil. However, the variety was not significantly different in oil content from other varieties when extraction by the solvent extraction method was used. That indicates that the Green Dwarf variety is not suitable for oil extraction by household method.

It seems that the oil content obtained by the household method is comparatively lower than that extracted by the solvent extraction method. In the household method, all the oil in the kernel may not be extracted in the coconut milk. And the residue may also contain some of the oil. In the household method the oil is extracted with water. Oil content on a wet basis is low compared to solvent extraction method, where oil is soluble in petroleum ether and almost all the oil can be extracted in it.

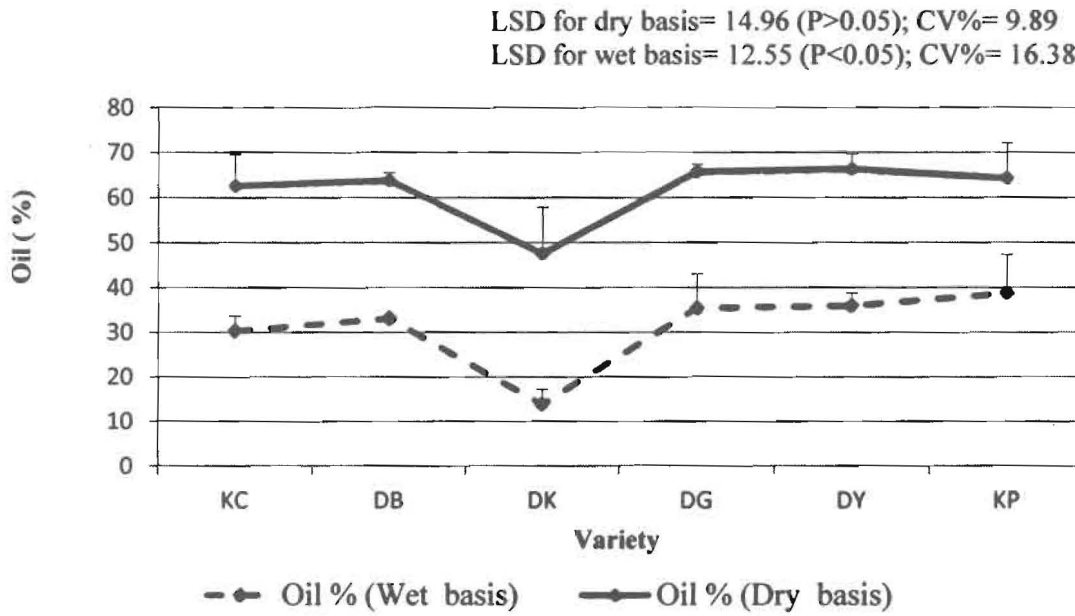

Figure 6: Extracted oil amount from solvent extraction method

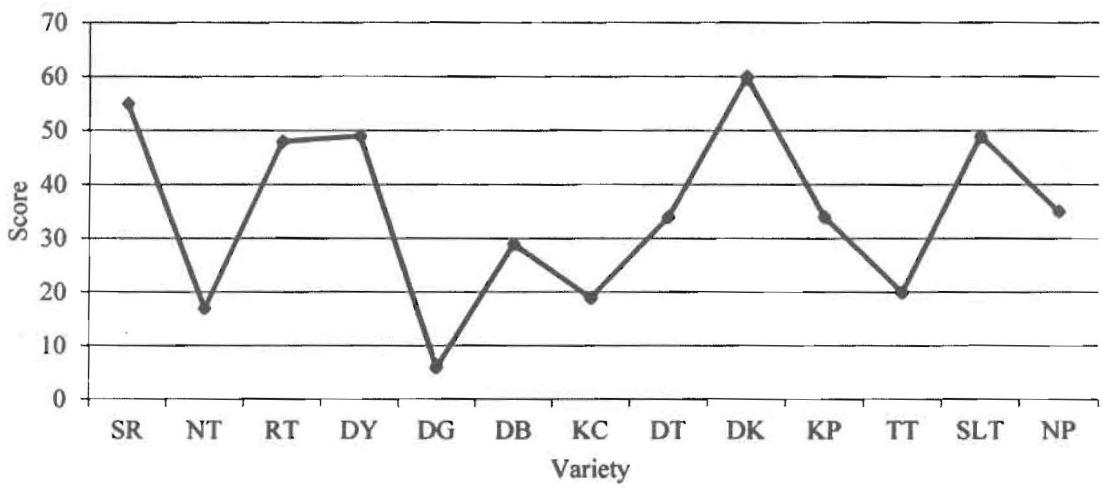

Figure 7: Overall comparison of morphological/physical properties of coconut

Overall comparison of morphological/physical properties

The overall comparison of the characteristics of varieties revealed that the normal Dikiri coconut showed the highest performances in the morphological/ physical characters followed by San Raman and the lowest performance was in Dwarf Green (Figure 7). In Dikiri coconut weight of nut, circumference, thickness of the kernel and extracted oil content were comparatively higher than other varieties.

The above mentioned morphological/ physical characters are extremely useful in the implementation of plant breeding programs. Therefore, varieties such as Dikiri, San Raman, Ran Thembili, Dwarf Yellow and Sri Lanka Tall can be recommended for the breeding programs to improve the above characters in the progeny.

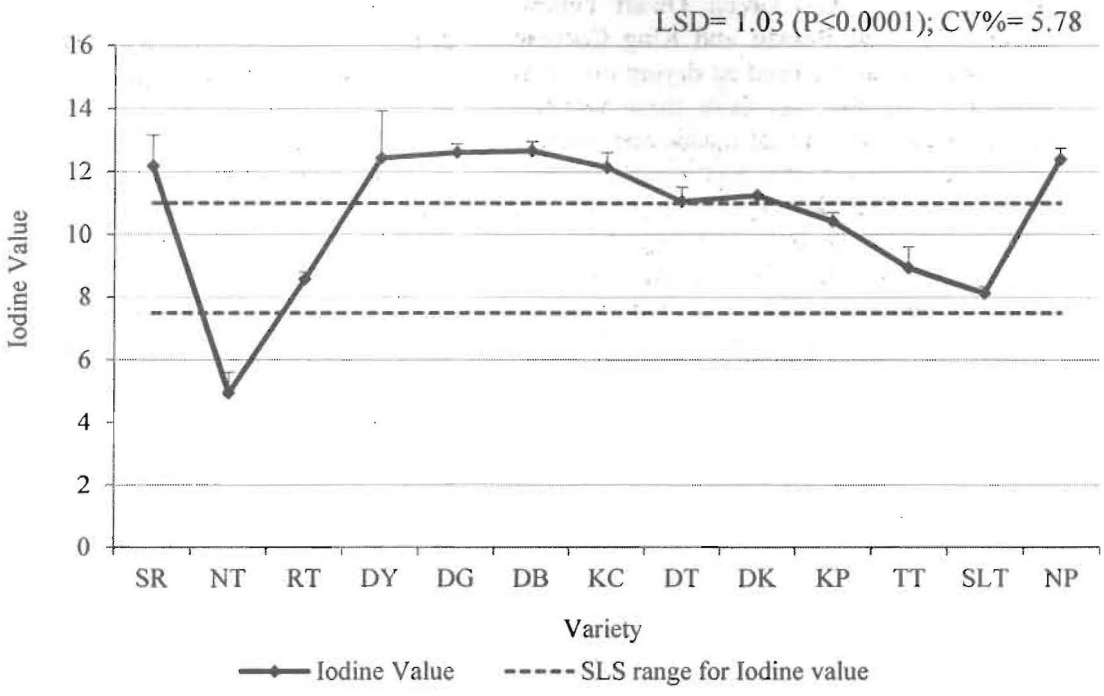

Figure 8: Variation of Iodine value

Quality of coconut oil

Saturation/unsaturation

Estimated Iodine values of the oil extracted from the thirteen coconut varieties showed significant variation (P<.0001) among varieties (Figure 8), which can be classified into four groups. Dwarf Brown, Dwarf Green, Dwarf Yellow, Nawasi Pol, San Raman and King Coconut are included in the first group with significantly highest Iodine values. The Dikiri, CRIC 65 and Kapruwana are placed in the second group and CRIC 60, Sri Lanka Tall and Ran Thambili are in the third. The final group includes only the Nawasi Thambili variety with a significantly low Iodine Value.

Only the Iodine value of Ran Thambili, CRIC 65, CRIC 60, Kapruwana and Sri Lanka Tall varieties were in the SLS range for untreated white coconut oil (Grade 3). All the above varieties are commercially cultivated in plantations except Ran Thambili. Therefore, the coconut oil in the market is dominantly made from these commercially cultivated palms. It is very rare to find other varieties from commercial plantations. Therefore, the proportional contribution of these minor varieties contribution to the changes of Iodine value is minimum. Hence the SLS range is fluctuating among the means of Iodine value of commercially cultivated varieties.

The Iodine value is a determination of the amount of unsaturated fatty acids and the unsaturation is in the form of double bonds which react with iodine compounds. The higher the iodine number, the greater number of the unsaturated fatty acid bonds present in a fat (wikipedia.org/wiki/iodine value 2010). Therefore, the varieties having high number of iodine value (Dwarf Brown, Dwarf Green, Dwarf Yellow, Nawasi Pol, San Raman and King Coconut) are more highly unsaturated than others. The coconut oil has generally 6% of unsaturated fatty acids but in these varieties this value may be higher. The Nawasi Thambili variety showed the lowest Iodine value of 4.96. This emphasizes that this variety has a higher saturation of fatty acids.

The Iodine value is a good parameter to compare the drying properties of oil. When the iodine value is high (more unsaturated) the

oils have high drying properties (Akinhanmi et al. 2008, 1-10). Therefore, the oils from Dwarf Brown, Dwarf Green, Dwarf Yellow, Nawasi Pol, San Raman and King Coconut like varieties can be used as drying oil. It is suggested that the oils from these varieties may be used as drying oil for the manufacture of cosmetics, oil paints and vanishes. They can also serve edible purposes for cooking or manufacture of margarine (Adelaja 2006).

The iodine value is also an index for assessing the capacity of oil for rancidity (Dawodu et al. 2009, 102-110). The low iodine values indicate that the oil had longer time to undergo oxidative deterioration. When the Iodine value is high, rancidity occurs more quickly. Therefore, the oil extracted from Dwarf Brown, Dwarf Green, Dwarf Yellow, Nawasi Pol, San Raman and King Coconut varieties can become rancid rapidly, with a short shelf life. The oil extracted from Nawasi Thambili showed the lower Iodine value and therefore it may become rancid slowly a long shelf life.

Characteristics of oil are changed with heating. Oil that is healthy at room temperature can become unhealthy when heated above certain temperatures. When choosing cooking oil, it is important to match the oil's heat tolerance with the cooking method. Polyunsaturated oil like soya, canola, sunflower, and corn oil degrade easily to toxic compounds when heated. Prolonged consumption of burnt oil could lead to atherosclerosis, inflammatory joint disease, and development of birth defects (wikipedia.org/wiki/Cooking oil 2010). Coconut oil is highly saturated oil and the ability of oil to change its characteristics due to heating is negligible. Thus, the highest saturation observed in the oil extracted from Nawasi Thembili variety indicates that it is the best variety for frying properties of food.

Saponification value

The saponification values of coconut oil from different varieties were estimated and (Figure 9) indicated that the highest saponification value was observed in Ran Thambili followed by Dikiri variety. Nawasi Thambili and Dwarf Yellow varieties showed the lowest values among the tested varieties.

The high saponification values recorded for the oil suggested that the oil contained high molecular weight fatty acids and low levels of impurities (Akanni et al. 2005; 177 - 181). Therefore, oil extracted from Ran Thembili and Dikiri varieties had high molecular weight compared to the other varieties. As well as longer chain fatty acids like stearic, oleic and linoleic acid. In contrast, Nawassi Thembili and Dwarf Yellow varieties should have the lowest average molecular weight.

Saponification is a chemical process that produces soap from fatty acid derivatives (wikipedia.org/wiki/Saponification2010). The higher the saponification value, the higher the ability of forming soap. Therefore, Ran Thambili and Dikiri varieties can be recommended for the production of soap. Based on the results Nawasi Thembili and Dwarf Yellow varieties cannot be recommended for the industrial production of soap.

According to the results, Nawasi Thembili and Dwarf Yellow varieties had the lowest average molecular weight hence the smallest molecular structure. Therefore, these two varieties can be used to produce ointments for body application. On the other hand the short and medium chain fatty acids are absorbed directly into the blood via intestine capillaries. Thus the above two varieties are good sources of coconut oil for human consumption.

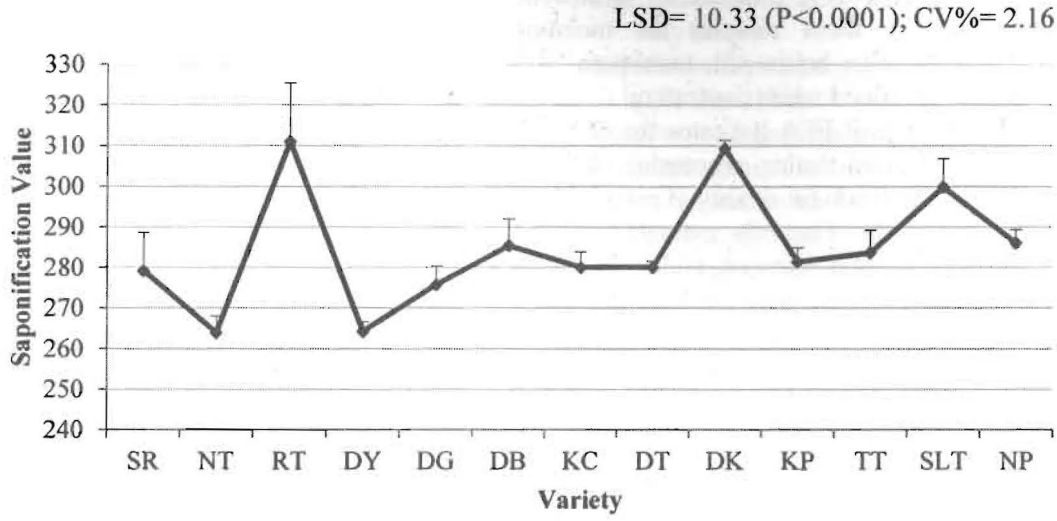

Figure 9: Variation of saponification value

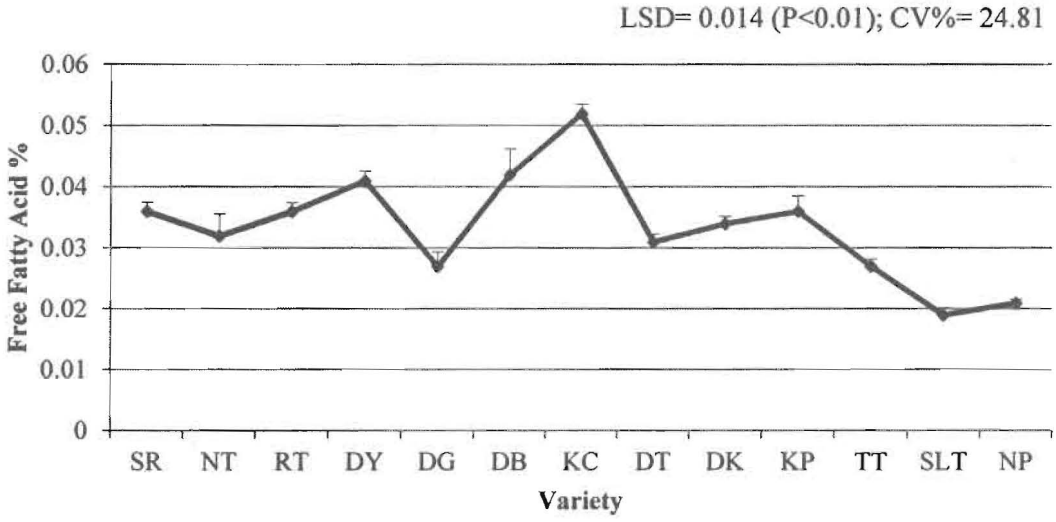

Figure 10 Variation of FFA of coconut oil in different varieties

Free fatty acid content (FFA)

The highest FFA value was observed in King Coconut and the lowest in Sri Lanka Tall variety (Figure 10).

Free fatty acids are fatty acids such as oleic, linoleic, stearic etc. that are not tied onto a glycerol molecule. It measures the percentage by weight of a specified fatty acid (Lawson et al. 1981, 265-273). For coconut oil the FFA is determined as lauric acid because it could account for up to 50% of the fatty acids in coconut oil (50.3%) (Krishnamurthi and Chandrasekharan 1983, 206-209).

The FFA values for all the samples were very low compared to the SLS maximum value of 0.8 for unrefined white oil. The highest initial FFA of the samples was 0.052 for the oil of King Coconut. Therefore, the oils take longer time to reach the maximum FFA level suitable for human consumption. Hence, the oils can be stored for extended periods without rancidity. Free Fatty Acids which are the result of the amount of hydrolysis of fat is affected by the presence of

moisture. So it is a measure of hydrolytic rancidity. For these samples the moisture content was also below the maximum SLS value for unrefined white coconut oil.

Percentage of FFA indicates the care and control exercised during processing. It is an indication of fresh fat quality (Lawson et al. 1984, 265-273). The oils extracted by the household method showed minimum FFAs indicating the care and control prevailing during processing.

In crude fat, free fatty acid estimates the amount of oil that will be lost during refining steps, designed to remove fatty acids (Lawson et al. 1984, 265-273). For the oils extracted from household method, refining is not necessary because initial FFA is present at minimum level.

The lower the FFA, the lower the free radicals present in oil. Once a free-radical reaction is started it can cause a chain reaction which produces more free radicals, which ultimately damages thousands of molecules. Free radical damage can only be restricted with antioxidants (www.coconut-connections.com, 2010). Free radical damage can cause many health problems like cancers (www.organicfacts.net, 010). In this respect the coconut oil made by the household method is very beneficial for the human health.

Peroxide value

The peroxide values in the oil samples were not observed the oil samples. If the oil is not rancid the peroxide value is minimum or nil. When a fat or oil is processed correctly and quickly a good quality oil is produced and the fresh peroxide value will be zero. It develops to a certain extent during storage and the quantity depends on time, temperature and exposure to air (Lawson et al. 1984, 265-273). In this analysis, the samples did not show any color change in the titration. This implies that processed correctly and quickly.

The unsaturated oil is subject to autoxidation due to the presence of double bonds in their molecular structure. When the saturation is high the oil does not undergo autoxidation reactions quickly (Lawson et al. 1984, 265-273). Therefore, the oil samples had not undergone autoxidation reactions.

Conclusions

The study on morphological/physical properties showed significant differences of the nut among thirteen different coconut varieties for weight of nut, circumference, thickness of the kernel and extracted oil content in household method. Dikiri and San Raman were the best varieties for the studied characters. The variety Dwarf Green was poor in all tested morphological/ physical characters.

According to the evaluation of quality parameters of extracted oil, Nawasi Thembili variety showed the highest saturation of fatty acids where Dwarf Green, Dwarf Yellow and Dwarf Brown varieties exhibited the comparatively the highest unsaturation. Ran Thembili and Dikiri varieties had the highest average molecular weight and Nawasi Thembili and Dwarf Yellow were the lowest. The maximum initial FFA value was observed in Ran Thembili variety followed by Dwarf Brown variety and the lowest was the Sri Lanka Tall variety. Just after extraction of coconut oil, autoxidation was not observed for any of the tested samples. Dwarf Green, Dikiri and Sri Lanka Tall varieties gave the highest amount of moisture content and Nawasi Thembili gave the lowest. The oil extracted from Dwarf Green, Dwarf Yellow, San Raman and Nawasi Thembili varieties showed the best quality for human consumption.

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