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Quantitative Models for Prediction of Palm Olein Adulteration in Coconut Testa Oil

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***Abstract*—**This study was carried out to produce quantitative models for prediction of palm olein (PO) adulterations in coconut testa oil (CTO) by using fatty acid compositional analysis and differential scanning calorimetric (DSC) analysis. Samples of authentic CTO were prepared using mature coconuts collected out of three local cultivars while a pure sample of PO was obtained from a reliable supplier. In this experiment, samples of CTO were blended with PO in the range of 20 to 80% (w/w) and subjected to fatty acid and thermal analysis using the relevant instruments. Fatty acid data and DSC data of thermal transitions namely, peak temperature, peak area, peak onset and peak endset temperatures were employed to perform statistical analysis. Results showed that all fatty acids were suitable as parameters to develop quantitative models for prediction of adulteration in CTO. The highest positive correlation was displayed by linoleic acid (+0.977; $p<0.0001$) followed by oleic (+0.973; $p<0.0001$), palmitic (+0.972; $p<0.0001$) and stearic (+0.959; $p<0.0001$) acids. Out of all, the two models formed using palmitic and oleic acids were the best for prediction. According to DSC analysis, the highest correlations were found for peak maxima (-0.965; $p<0.0001$) and peak area (-0.951; $p<0.0001$). Out of these two, the model formed using peak maxima was the best for prediction.

***Keywords*—**Authentication; coconut testa oil; DSC; fatty acid composition; palm olein

I. Introduction

Coconut testa (CT) is the brown color thin layer occurring on top of the white kernel of the coconut fruit. CT is often removed prior to processing of the kernel into products owing to its dark brown color (Gunarathna *et al*., 2022). Removal of the CT of coconut is generally carried out by using manually-operated paring knives in several developing countries (Marasinghe *et al*., 2019). As the perfection of the job is said to be dependent on the skills of the factory workers, the amount of testa removed might vary leading to non-uniformity in losses. According to some previous estimates, approximately 18 % of the total kernel (w/w, wet basis) is lost during removal of testa (Gunarathna *et al*., 2022). When considering the current economic value of coconut, loss due to removal of coconut testa is considerably high. CT is therefore most likely to be used for extraction of oil known as coconut testa oil (CTO) due to its high content of lipids (Marasinghe *et al*., 2019).

Coconut oils of various grades are found to exist in the markets across the major producing countries. At times, some confusion could arise regarding the identity characteristics of coconut testa oil (CTO) in the oil trade and business; CTO might be mistaken with ordinary coconut oil, which is produced from dried copra of coconut. Despite the differences in some quality characteristics, particularly related to iodine value and fatty acid composition, CTO has been used to adulterate ordinary coconut oil to increase the profit margin. Owing to this reason, principle principal component analysis of fatty acid data was used by researchers in the past to distinguish CTO from ordinary coconut oil (Marikkar and Nasyrah, 2012). In recent times, CTO has been sold as a separate oil product under the brand name of 'testa coconut oil' due to ever increasing demand for coconut oil in the local market. As this is an oil product with a new label in the market, consumers might be unaware of its correct quality identity. This would eventually lead to traders in oil business attempting to adulterate CTO with palm olein, which is a cheaper substance. In the meantime, food control authorities in some countries have taken initiative to impose a ban on mixing of coconut oil with other cheaper oils to safeguard consumers. This may eventually warrant the compilation of analytical data to authenticate CTO from those formed by adulteration practices. This kind of information would be greatly beneficial to food control authorities to curb fraudulent practices, which are contrary to the food act enacted in many countries (Johnson, 2014).

Starting from the early nineteen nineties, a growing interest has been seen among researchers to use different analytical approaches to authenticate various commercial oils (Cecchi *et al*., 2021), cocoa butter (Perez *et al*., 2020), dietary

supplement oils etc (Ozen *et al*., 2003). Gas chromatography (GLC), differential scanning calorimetry (DSC) and FTIR spectroscopy have been among the analytical techniques tried and tested by experts in the field of fats and oils. Particularly, DSC has received much attention from researchers around the world as an effective authentication approach for various oils and fats (Mansor *et al*., 2012). etc. As the thermodynamic phase transitions occurring in DSC curves of natural lipids are closely related to their chemical composition, DSC was employed in the past to detect deviations caused by food adulterations (Marikkar *et al*., 2022; Chiavaro *et al*., 2008). A brief survey of the literature would show that the information dealing with authentication of CTO or detecting its adulterations with other cheaper oils are scanty. Hence, it is intended in this study to produce quantitative prediction models for predicting adulteration of CTO using fatty acid compositional data and DSC heating curve thermal parameters as reference for quality assurance purposes.

II. Materials and Methods

A. Materials

Twelve months-old coconuts of three locally grown cultivars [Tall x Tall (TT), San Raman Tall (SR) and Commercial (COM)] raised in the varietal blocks of Coconut Research Institute, Sri Lanka were collected as samples for this study.

B. Sample oil extraction

Fresh CT of individual cultivar of coconut were peeled off from their kernel and disintegrated into medium sized particles using a disintegrator (Unitex Engineers, Sri Lanka). After drying at 70°C in a cabinet-type dehydrator (Wessberg, Martin, Germany) for 8 h, CT samples of each cultivar were subjected to cold press oil extraction using a micro oil expeller (Komet DD85 machine, Germany). CTO sample of each cultivar was purified by allowing gravitational filtration overnight (Marasinghe *et al*., 2019).

C. Fatty Acid compositional analysis

A sample portion of oil (0.4 g) was weighed into screw capped glass tubes and added 4.0 ml portion of methanol and 0.1 mL portion of methanolic KOH. Mixture was heated to 60 C in a water bath for 10 min and allowed to cool. Into this, 2 mL portion of hexane and 4 ml portion of distilled water were added. Contents were agitated at 2500 rpm for 10 min in a vortex. After allowing the content to undergo layer separation, the upper layer was used to inject into a gas chromatography (GC-2010 Shimadzu Corporation, Japan) fitted with a flame ionization (FID) detector. The temperature of the oven was programmed as follows: the initial temperature was 130 °C (1 min hold), then rose from 130 to 170 °C (6.5 °C min-1), 170 to 215 °C (2.75 °C min-1) and maintained at 215 °C for 12 min. Then, the temperature was increased from 215 to 230 °C (4 °C min-1) and remained for 3 min. The temperatures of injector and detector were maintained at 270 °C and 280 °C, respectively. Hydrogen was used as the carrier gas at constant pressure mode of 43 cm/sec. Split ratio of the injector was 50:1. Retention time of each peak was compared with that of standard fatty acid methyl esters to identify individual fatty acids (Supelco, Bellefonte,PA). Percentage of individual fatty acid was calculated by dividing the peak area of each fatty acid by the total of the entire peak areas of all fatty acids (Marasinghe *et al*., 2019).

D. Thermal analysis by DSC

DSC analyses were performed in accordance with a method described before (Marikkar *et al*., 2012). The instrument used was Q200 differential scanning calorimeter, with aluminium T zero pan with T zero hermetic lid (TA Instruments, USA). Nitrogen gas of 99.9% purity was used as the purge gas at the rate of 50.00 mL/min. For each analysis, approximately 8-10 mg sample (in liquid state) was weighed into a standard DSC aluminium pan and sealed hermetically. A hermetically sealed empty aluminum pan was used as reference. The thermal curves were obtained by following the temperature program; -30 ℃ isotherm for 1 min, heated at the rate of 5 ℃/ min to 40 ℃, isotherm for 1 min at 40 ℃.

E. Statistical analysis

The results of all analyses were reported as mean ± standard deviation values. Data were statistically analyzed by one-way analysis of variance (ANOVA) using Tukey's Test of MINITAB (version 20.3) statistical package at 0.05 probability level. Pearson's correlation analysis was performed for fatty acids and DSC parameters with varying levels of adulteration. The predictive models based on either individual fatty acid or each DSC parameter were developed using regression analysis procedure of the Minitab statistical data package. Statistical significance was declared at 0.05 probability level. Stepwise multiple linear regression (SMLR) analysis was performed for independent variables. During the execution of the stepwise procedure in the Minitab, the significant level of an independent variable for entry and stay in the quantitative model was set to 0.15 (Marikkar and Rana, 2014).

III. Results and Discussion

A. Predictive model using GLC fatty acid data

Fatty acid distribution of CTO of three coconut cultivars namely, SR, TT, and COM are compared as shown in Table I. The inter-varietal differences in the distribution of individual fatty acid among the different cultivars are of considerable importance from quality assurance and nutritional point of view.

According to Table I, lauric (C12:0) is the most dominant fatty acid followed by myristic (C14:0) acid. With regard to the amounts of lauric and myristic acids, no significant ($p>0.05$) differences were observed between TT and SR. However, the proportions of these two fatty acids in COM were significantly ($p<0.05$) different from the other two. Palmitic (C16:0) is the third most abundant fatty acid

Table I: Distribution of fatty acids in coconut testa oil, palm olein and their blends

Oil sample	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2
SR	7.62 ± 0.01^{e}	4.96±0.01^{f}	45.48±0.03^{f}	20.25±0^{f}	9.84±0.03^{b}	2.23±0.69^{db}	7.22±0.65 $^{a, b}$	2.38±0.0^{b}
TT	8.14±0.03^{f}	5.21±0.04^{g}	45.29±0.11^{f}	20.2±0.04^{f}	9.43±0.04^{a}	2.52±0.11^{d}	7.09±0.05 $^{a, b}$	2.09±0.04^{a}
COM	7.33±0.01^{d}	4.45±0.03^{e}	42.65±0.21^{e}	21.15±0.21^{g}	10.24±0.04^{c}	2.92±0.02^{d}	7.91±0.01^{b}	3.28±0.02^{b}
20% PO	7.56 ± 0.01^{e}	4.33 ± 0.06^{de}	41.88 ± 0.18^{e}	17.86 ± 0.04^{e}	11.71 ± 0.10^{c}	1.24 ± 0.03^{a}	11.68 ± 0.04^{c}	3.76 ± 0.04^{c}
40% PO	6.94 ± 0.49^{cd}	3.92 ± 0.25^{d}	37.41 ± 1.37^{d}	15.22 ± 0.02^{d}	14.74 ± 0.91^{d}	1.94 ± 0.06^{bc}	15.63 ± 0.95^{d}	4.86 ± 0.16^{d}
60% PO	5.58 ± 0.03^{c}	3.14 ± 0.06^{c}	29.16 ± 0.39^{c}	11.99 ± 0.23^{c}	19.90 ± 0.39^{e}	1.53 ± 0.01^{b}	22.12 ± 0.22^{e}	6.61 ± 0.10^{e}
80% PO	3.63 ± 0.24^{b}	2.09 ± 0.13^{b}	18.88 ± 0.22^{b}	7.87 ± 0.12^{b}	26.47 ± 0.36^{f}	1.71 ± 0.06^{b}	30.28 ± 0.33^{f}	9.10 ± 0.27^{f}
PO	0 ± 0.00^{a}	0 ± 0.00^{a}	0 ± 0.00^{a}	1.28 ± 0.07^{a}	38.11 ± 0.05^{g}	2.26 ± 0.01^{d}	45.27 ± 0.09^{g}	13.10 ± 0.13^{g}

[1]Each value in the table represents the mean of replicates. Means that do not share a same superscript letter within the columns are significantly different at 95% confident (α=0.05). Abbreviations: COM, commercial hybrid; SR, San Raman; TT, Tall x Tall; PO, Palm olein.

of the three CTO samples (9.43-10.24%). The unsaturated fatty acids such as oleic (C18:1) and linoleic (C18:2) were detected in lesser amounts among the three CTO samples. The proportion of oleic (C18:1) acid among the cultivars was relatively higher than that of linoleic acid (C18:2). As a noteworthy feature, shorter chain fatty acids such as caprylic (C8:0) and caproic (C10:0) were found to occur in lesser amounts in all three CTO samples. This is in accordance with the findings reported from other parts of the world (Appiah *et al*., 2021; Ramesh *et al*., 2022). Although there was a significant (p<0.05) difference with regard to the distribution of these fatty acids, but their differences were minute among the cultivars.

The potential adulterant used in this study was palm olein, which has oleic and palmitic acids as the two major fatty acids (Table I). The proportions of these two fatty acids were agreeable with the findings reported previously. It should be noted that the third most abundant fatty acid of palm olein used in this study was linoleic acid. In response to the increasing proportion of PO in the blends, the proportions of caprylic (C8:0), caproic (C10:0), lauric (C12:0) and myristic acid (C14:0) were found to decline while the proportions of other fatty acids namely palmitic (C16:0), oleic (C18:1) and linoleic (C18:2) were steadily increased (Table I). Pearson's correlation analysis between individual fatty acid and the percentage levels of the adulterant is shown in Table II. According to Table II, all eight fatty acids displayed strong correlations with the increasing level of adulteration. Fatty acid namely caprylic (C8:0), caproic (C10:0), lauric (C12:0) and myristic acid showed negative correlation, while fatty acid such as palmitic (C16:0), stearic (C18:0), oleic (C18:1) and linoleic (C18:2) displayed positive correlation. The highest positive correlation was displayed by linoleic acid (+0.977; p<0.0001) followed by oleic (+0.973; p<0.0001), palmitic (+0.972; p<0.0001) and stearic (+0.959; p<0.0001) acid. The highest negative correlation was noted for lauric acid (-0.972; p<0.0001) followed by capric (-0.969; p<0.0001), myristic (-0.968; p<0.0001) and caprylic (-0.965; p<0.0001) acid. These will remain true only when palm olein is used as the adulterant in CTO.

According to these results, all eight fatty acids were suitable as parameters in the stepwise procedure to develop predictive models for quantification of the adulteration. The outcome of the stepwise procedure as given in Table III shows that all eight models are suitable for quantitative prediction as they all display high coefficient of determination (R^2) with a good confidence limits. Nevertheless, model number 5 [Y = + 0.03510 Palmitic -0.2160] and 7 [Y = + 0.02748 Oleic -0.1222] are preferred over the others as they displayed the highest values of coefficient of determination (R^2= 0.95) with good confidence limits (p<0.0001) In addition to this, both of these models were also found to display the lowest values for standard error of prediction (SE). These were actually considered as the basis for development of predictive models for various purposes. For instance, Marikkar and Rana (2014) previously considered highest coefficient of determination (R^2 value) with good confidence limit and smallest standard error as the basis for more accurate predictive models to determine lard stearin content in canola oil. In another study, a model based on the highest coefficient of determination (R^2 value) with a good confidence limit and smallest standard error was selected for prediction of iodine values of coconut oil using fatty acid data (Marikkar *et al*., 2008).

Table II: Pearson correlation coefficient between individual fatty acid content and adulteration level (%).

Fatty acid	r value	*p* value
Caprylic	-0.965	0.0001
Capric	-0.969	0.0001
Lauric	-0.972	0.0001
Myristic	-0.968	0.0001
Palmitic	0.972	0.0001
Stearic	0.959	0.0001
Oleic	0.973	0.0001
Linoleic	0.977	0.0001

r, Pearson correlation coefficient, all correlations are significant (p<0.05)

According to the results of this study, fatty acid compositions of the adulterated samples were affected to varying extent depending on the levels of adulterations. This has led to development of models using fatty acid data for quantitative estimation. In parallel to the calibration sample set, another set of sample should be analyzed for validation of these models. It is worthwhile to mention about the applicability of this method for routine-check for adulterations in

Table III: Simple regression analysis for prediction of adulteration levels based on individual fatty acid content (%)

Item	Fatty acid	Regression equation	R^2	*p* value	SE
1	Caprylic	Y = - 0.11196 Caprylic + 1.1023	0.93	0.0001	0.008
2	Capric	Y = - 0.1923 Capric + 1.0952	0.94	0.0001	0.013
3	Lauric	Y = - 0.02187 Lauric + 1.1211	0.94	0.0001	0.001
4	Myristic	Y = - 0.05812 Myristic + 1.1838	0.94	0.0001	0.004
5	Palmitic	Y = + 0.03510 Palmitic -0.2160	0.95	0.0001	0.002
6	Stearic	Y = + 0.8284 Stearic -0.7625	0.92	0.0001	0.066
7	Oleic	Y = + 0.02748 Oleic -0.1222	0.95	0.0001	0.002
8	Linoleic	Y = + 0.09545 Linoleic -0.1433	0.95	0.0001	0.006

Y, % of adulteration; R^2, coefficient of determination; SE, standard error coefficient; all correlations are significant ($p<0.05$)

CTO. If remarkable deviations in fatty acid composition of a randomly selected sample was observed, it would indicate possible adulteration. In such cases, fatty acid values of both palmitic and oleic acids should be taken out and substituted in the models developed in Table III. In this way, the extent of adulteration could be quantified from the calculation.

B. Predictive model using DSC data

DSC heating curves of CTO obtained from three different local cultivars are compared as shown in Fig 1(A). Based on the patterns, the heating curves of CTO of the three local cultivars are roughly similar. In the heating curves, the peak maxima of the most prominent peak of TT and SR cultivars were at 24.65 ºC and 24.54 ºC, respectively (Table IV). In the case of COM cultivar, the peak maximum of the prominent peak was found at 25.42 ºC along with a minor shoulder peak at 15.05 ºC. The peak area of these thermal transitions corresponding to TT, SR and COM were 93.51, 94.85, and 94.12 J/g, respectively. Among the three cultivars, no significant ($p>0.05$) differences was found with regard to these values. Both TT and COM showed similar ($p>0.05$) values with regard to the onset temperature, but SR showed a value that was significantly ($p<0.05$) different. TT showed a significantly different ($p<0.05$) value for the end-set temperature, when compared to SR and COM cultivars.

The heating curve of PO, on the other hand, exhibited considerable differences from CTO in terms of thermal profile [Fig 1(B)]. The major thermal transition peak of PO was found at 4.43 ºC, which had its onset at -15.97 ºC and continued till 23.17 ºC. According to thermal transition values presented in Table IV, significant ($p<0.05$) differences were seen between the DSC values of CTO and PO. The overlay of DSC curves presented in [Fig 1(B)] compares the heating curve of CTO of COM cultivar with those of the adulterated mixtures (20 to 80 %, w/w). When the percentage of adulteration went up, the sharpness of the major melting peak decreased and turned into a broad blunt peak resulting in the reduced enthalpy of melting [Fig 1(B)]. As shown in Table IV, with the increasing level of adulteration of CTO, the peak maxima, peak-onset and peak-endset temperatures of the thermal transitions of the adulterated samples were shifted to low temperature region while affecting the peak-area and the peak-shape of the heating curves.

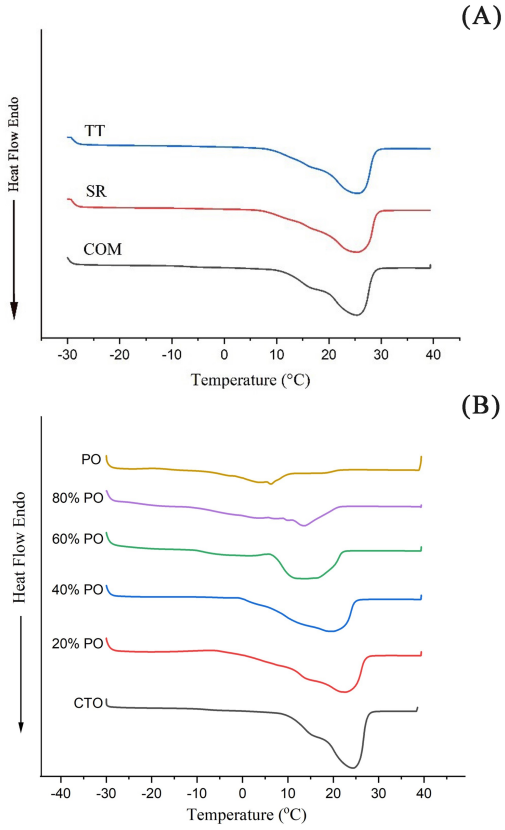

Figure 1: DSC heating curves of CTO of individual coconut cultivars (A) and DSC heating thermograms of coconut testa oil (CTO), palm olein (PO), and CTO adulterated with 20 % PO, 40 % PO, 60 % PO, and 80 % PO (B). Abbreviations: TT (curve TT), SR (curve SR) and COM (curve COM)

As shown in Table IV, the peak maxima of adulterated oil samples of A1 (20% PO), A2 (40% PO), A3 (60% PO) and A4 (80% PO) were at 22.29 ºC, 20.41 ºC, 14.57 ºC, and 14.26 ºC, respectively. Likewise, the onset of adulterated oil samples of A1 (20% PO), A2 (40% PO), A3 (60% PO) and A4 (80% PO) were at -5.69 ºC, -11.42 ºC, -10.95 ºC, and -12.12 ºC, respectively. As discussed previously, this shifting phenomenon is attributed to the chemical compositional changes caused by adulteration of CTO (Table IV). For the purpose of statistical analysis of heating curve data, samples A1 (20% PO), A2 (40% PO), A3 (60% PO) and A4 (80% PO) were included. According to Pearson's correlation analysis of the percentage of PO adulteration level with DSC parameters of the relevant thermal curves, all DSC parameters of the heating curves displayed strong negative correlations with the percent-adulteration, where peak maxima and onset temperatures resulted in the highest ($r= -0.965$; $p<0.0001$) and the lowest ($r= -0.919$; $p<0.001$) correlation coefficient, respectively (Table V). These will remain true only when palm olein is used as the adulterant in CTO.

The results of the simple regression analysis of each DSC parameter with percentage adulterations are shown in Table

Table IV: Comparison of DSC parameters of heating curves obtained from coconut testa oil and its palm olein admixtures

Sample	Peak maxima (°C)	Onset (°C)	End set (°C)	Peak area(J/g)
TT cultivar	24.65 ± 0.21^{e}	6.17 ± 0.01^{f}	28.68 ± 0.09^{c}	93.51 ± 0.17^{e}
SR cultivar	24.54 ± 0.09^{e}	5.2 ± 0.15^{e}	29.26 ± 0.11^{d}	94.85 ± 0.15^{e}
COM cultivar	25.42 ± 0.13^{e}	7.08 ± 0.21^{f}	30.30 ± 0.03^{d}	94.12 ± 0.05^{e}
A_1 (20% PO)	22.29 ± 0.87^{d}	-5.69 ± 0.04^{d}	28.57 ± 0.25^{c}	94.06 ± 0.09^{e}
A_2 (40% PO)	20.41 ± 0.14^{c}	-11.42 ± 0.24^{c}	27.45 ± 0.16^{b}	82.51 ± 0.19^{d}
A_3 (60% PO)	14.57 ± 0.09^{b}	-10.95 ± 0.16^{c}	23.54 ± 0.05^{a}	63.76 ± 0.14^{c}
A_4 (80% PO)	14.26 ± 0.22^{b}	-12.12 ± 0.01^{b}	23.26 ± 0.08^{a}	51.44 ± 0.28^{b}
PO	4.43 ± 0.07^{a}	-15.97 ± 0.05^{a}	23.17 ± 0.05^{a}	31.02 ± 0.01^{a}

Each value in the table represents the mean of replicates. Means within columns with different superscripts are significantly different at 95% confident (α=0.05). Abbreviations: TT, TallxTall; SR, San Ramon; COM, commercial hybrid; PO, Palm olein; A_1, 80:20; A_2, 60:40; A_3, 40:60; A_4, 20:80.

Table V: Pearson correlation coefficient between adulteration level (% of PO) and individual DSC parameter of heating curves

DSC analysis type	DSC parameter	r value	*p* value
Heating curve	Peak maxima	-0.965	0.0001
	Onset	-0.919	0.001
	Endset	-0.950	0.0001
	Peak area	-0.951	0.0001

r, Pearson correlation coefficient, *non- significant (p> 0.05) correlation

VI. Among the models developed using the heating curve, Y = - 5.195 peak maxima + 135.3 [R^2= 0.93; p< 0.0001 and SE=0.17] was the best predictive regression model based on the highest correlation and smallest SE.

According to the results of this study, shape of the DSC curves of CTO of the three cultivars apparently looks similar with slight differences. As for method validation, this can be cross-checked with CTO obtained from other cultivars locally distributed. This study indicated that the shapes of the DSC heating curves were affected to varying extent depending on the levels of adulterations. This has led to development of models using DSC data for quantitative estimation. In parallel to the calibration sample set, another set of sample should be analyzed for validation of the models developed. It is worthwhile to mention about the applicability of this method for routine-check for adulterations in CTO. In a randomly selected sample from the market, if remarkable deviations in DSC thermal curve were observed, it would indicate possible adulteration with another oil. In such cases, DSC parameters of the suspected sample should be obtained and substituted in the models developed in Table IV. In this way, the extent of adulteration could be quantified from the calculation.

IV. Conclusion

This study demonstrated that the prediction of adulteration in CTO was mainly based on deviations in the existing fatty acids and thermal transitions in DSC heating curves. When CTO was adulterated with PO, all eight fatty acids were found to be suitable as parameters in the stepwise procedure to develop predictive models for quantification of adulteration. Among them, model of Y = + 0.03510 Palmitic -0.2160 and Y = + 0.02748 Oleic -0.1222 are preferred very much as they displayed the highest coefficient of determination (R^2= 0.95) with good confidence limits (p<0.0001) and smallest SE value. DSC analysis showed that the DSC peak of the heating curve found at 25.42 °C was greatly influenced by adulteration and exhibited significant (p<0.05) deviations in response to the increasing level of adulteration. For quantitative prediction, the model obtained using the peak maxima of the DSC heating curve would be more suitable as it had displayed the highest R^2 value with lower smallest SE. DSC parameters of the peaks namely peak area, peak onset and peak temperature were found to be useful as parameters in obtaining quantitative models.

V. Conflict of Interest

Authors would like to declare that there is no conflict of interest.

VI. Acknowledgement

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Table VI: Simple regression analysis carried out for prediction of adulteration levels based on individual DSC parameter of heating curves

DSC analysis type	Regression equation	R^2	P value	SE
Heating curve				
1	Y = - 5.195 peak maxima + 135.3	0.93	0.0001	0.17
2	Y = - 3.781 onset + 19.21	0.85	0.001	0.66
3	Y = - 12.54 endset + 373.3	0.90	0.0001	1.68
4	Y = - 1.356 peak area + 139.1	0.90	0.0001	0.18

Y, % of adulteration; R^2, coefficient of determination, SE, standard error coefficient. The parameters; peak maxima, onset and endset measured in ° C while peak area measured in J/g. The developed model is only applicable to detect up to 60% of adulteration levels; [1]non-significant ($p>0.05$) regression.

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