An Investigation of Food Quality and Oil Stability Indices of Muruku by Cluster Analysis and Discriminant Analysis

Abbas F.M. Alkarkhi[#], Nik Aisyah Nik Muhammad[*],
Wasin A. A. Alqaraghuli[$], Yusri Yusup[*], Azhar Mat Easa[*], Nurul Huda[^]

[#]*Universiti Kuala Lumpur, Malaysian Institute of Chemical and Bioengineering Technology (UniKL MICET),
78000 Alor Gajah, Melaka Malaysia
E-mail:abbas@unikl.edu.my*

[*]*School of Industrial Technology, Universiti Sains Malaysia, Minden, 11800, Pulau Pinang, Malaysia*

[$]*School of Mathematical Sciences, Universiti Sains Malaysia, Minden, 11800, Pulau Pinang, Malaysia*

[^]*School of Food industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Terengganu Darul Iman, Malaysia*

Abstract— **In the present study, the quality of Muruku, a popular Indian traditional snack prepared by deep frying, was determined. Seven different brands or types of Muruku were obtained based on packaging types. The average fat and moisture content were 29.27% to 45.47% and 0.73% to 5.35%, respectively. The ratio of polyunsaturated to saturated fatty acids falls within the healthy range of 0.20 to 0.33. The oil indices analysis showed that the values of peroxide (PV), p-anisidine (PAV), acid value (AV) and thiobarbituric acid (TBA) of the oil extracted from the Muruku were in the range of 3.52 to 10.27 meq O2/kg, 3.67 to 14.04, 3.71 to 15.73 mg KOH/g and 2.42 to 38.59 mg malonaldehyde eq/kg, respectively. Cluster analysis grouped the samples into four groups indicating differences in the quality of the snack. Discriminant analysis showed that average lightness, redness, yellowness values, saturated fatty acids content, TBA, PAV, and moisture content were the main contributors in discriminating the samples. This suggests that most of the Muruku samples were subjected secondary oxidation either due to long storage because of inappropriate packaging technology employed or exposure to light and heat, which may increase the risk of rancidity and toxicity.**

Keywords— **deep frying; oxidative rancidity; lipid oxidation indices; cluster analysis; discriminant analysis**

I. INTRODUCTION

Muruku is one of the most widely consumed traditional snacks in India, Malaysia, and Singapore. It is an extruded noodle-like snack made from a mixture of dhal flour, spices, salt, and sugar, prepared by deep fat frying. During frying, the flour mixture is immersed in hot edible oil between 140 and 180°C [1]. A large portion of the snack comprises of the retained oil, which is prone to oxidative degradation. The repeated use of frying oil or the use of low-quality oil could also reduce oil stability and lower the overall quality of the Muruku. Moreover, since oxidation is a function of light and temperature, Muruku quality is dependent on its packaging type, which could affect its shelf life.

Oil oxidation processes occur in three phases: an initiation phase, a propagation phase, and a termination phase. In the initiation phase, molecular oxygen combines with unsaturated fatty acids to produce reactive hydroperoxides and free radicals. This reaction can increase if oxidative initiators such as chemical oxidisers, transition metals or enzymes are present. Heat and light also increase the rate of initiation and other phases of lipid oxidation, hence the relationship between packaging and oxidation. The reactive products of the initiation phase will, in turn, react with additional lipid molecules to form other reactive chemical compounds, also referred to as "auto-oxidation". The termination phase is the formation of unreactive compounds such as hydrocarbons, aldehydes, and ketones, which results in the food turning rancid.

A number of studies reported the impact of oil oxidation on food quality. These include the effects of types of packaging material on physicochemical and sensory characteristics of deep fat fried banana chips [2], quality characteristic and shelf life studies of deep fried snack

prepared from broken rice and legumes by-product [3] and physicochemical and sensory evaluation of fried banana [4]. Other studies on Asian snacks are the effects of the repetitive use of cooking oil on the quality of tempeh (fermented soybean), catfish and fried chicken [5] and oxidative instability of the cooking oil used to deep fry *keropok lekors* or fish crackers [6]. These studies have shown that oxidation caused degradation of oil stability and contributed to an overall decrease in product quality.

The principal health concern of fried foods is the rancidity of the oil caused by oxidation [7], and therefore, oil retained in the fried food can be an important quality indicator. Thus, what are the qualities of Muruku available in the market? Are the Muruku of different types or brands differ widely in quality? Could this be caused by the different packaging used by the producer? Food quality can be determined by its colour, fat and moisture content while the degree of oxidation from the lipid oxidation indices. Lipid oxidation indices include the peroxide, p-anisidine, acid, thiobarbituric acid content and fatty acid composition. Hierarchal clustering and dimension reduction statistical analyses of the above quality parameters will assist in categorising the Muruku based on quality parameters to determine its variation in the market and the possible association with packaging depending on the brands or types.

There is limited study has been conducted on the characteristics of Muruku quality commonly available in the market. Therefore, in this study, different types or sources of Muruku of different oil quality and packaging were sampled and analysed to assess the effects of oil oxidation and packaging type on Muruku quality.

II. MATERIAL AND METHODS

A. Sample Preparation

Seven different types or brands of Muruku samples were obtained on the same day from several different markets. Muruku sample 1 (designated as M1) was prepared fresh by a street vendor and then packed in low-density polyethylene bags. Muruku samples 2, 3, 4 and 5 (designated as M2, M3, M4, and M5, respectively) were purchased from various markets and packed in transparent polypropylene plastic bags. Muruku sample 6 (designated as M6) was obtained from an established supermarket chain and packed in polypropylene semi-metallised plastic zip-lock bags with a transparent window, whilst Muruku sample 7 (designated as M7) was obtained from a 24-hour chain store and packed in opaque polypropylene plastic bags with a transparent window. The details of the samples are listed in Table 1. None of the samples were vacuum-packed. Basic data such as weight, price (in USD) per gram, types of packaging and expiration dates were noted. Note that samples M1 and M5 did not disclose its expiration dates. All proceeding chemical analyses were done in triplicates.

TABLE I
BASIC INFORMATION OF THE MURUKU SAMPLES

Samples	Price ($)	Quantity (g)	Price per g ($/g)	Moisture content (%)	Types of packaging	Expiry date
M1	1.33	100	0.0133	0.73 ± 0.12	Low Density Polyethylene (transparent)	*N/A
M2	0.93	300	0.0031	2.73 ± 0.11	Polypropylene (transparent)	Available
M3	0.34	100	0.0034	4.50 ± 0.28	Polypropylene (transparent)	Available
M4	0.72	200	0.0039	4.04 ± 0.21	Polypropylene (transparent)	Available
M5	1.33	250	0.0053	5.35 ± 0.16	Polypropylene (transparent)	*N/A
M6	0.67	180	0.0037	3.84 ± 0.10	Semi Metallised plastic zip-lock bag (with a small clear widow)	Available
M7	1.20	180	0.0067	1.48 ± 0.12	Polypropylene (with a small clear window)	Available

*N/A: Not available. M1 was prepared fresh by a street vendor; M5, no expiry date found on the packaging

B. Oil Sample Preparation

Muruku samples were grounded using a blender (BL-114, Tefal) and then oil-extracted by using the Fat Analysis System FOSS/Soxtec 2050 (FOSS, Denmark). Muruku samples of 10 g were weighed inside 33-mm thimbles; fat-free cotton wools were later plugged on top of the thimbles. Petroleum ether of 90 ml at 35-60°C was added to the Soxhlet extractor flask. The thimbles were placed in the Soxtec extractor together with the flask, and the system was operated for two hours. The extracted oil trapped in the flasks were placed in an oven at 105°C for two hours and later cooled in a desiccator.

C. Colour, Fat And Moisture Content Analyses

Colour measurements of the extracted oil were determined using a colorimeter (Minolta CM-3500d, Minolta Co. Ltd., Japan) installed with the Spectra Magic software (version 2.11) with CIE. The parameters measured were L*, which represents the lightness or brightness, a*, which represents the greenness (-a*) and redness (+a*) and b*, which represents the blueness (-b*) and (+b*) yellowness, respectively.

Fat content (FC) was determined according to the AOAC [8] method by using the fat analysis system FOSS/Soxtec 2050 (FOSS, Denmark) auto extractor with petroleum ether as a solvent. Moisture content (MC) was determined by using the moisture analyser MX-50 (A&D Company Limited). The moisture analyser was preheated to 105°C before 5 g of grounded samples were added evenly on the plate inside the analyser.

D. Lipid Oxidation Indices

The oil extracted from the samples were analysed for peroxide, p-anisidine, acid, thiobarbituric acid and fatty acid composition. Peroxide value (PV) was determined according

to standard AOAC 965.33 method [8]. Five grams of oil were weighed and placed in a 250 mL conical flask and mixed with a solvent mixture containing 1 mL acetic acid and 12 mL chloroform. While swirling the mixture, 0.5 mL of saturated potassium iodide solution was added and swirled while adding 30 mL of distilled water and a few drops of 10% starch solution. The solution was titrated against 0.01 M sodium thiosulphate solution. The PV was expressed in milliequivalents (meq) of peroxide per kg of the sample calculated, as per Eq. (1),

$$PV = \frac{S \times M_{Na_2S_2O_3}}{m \times 1000} \quad (1)$$

where S is the volume of sodium thiosulfate ($Na_2S_2O_3$) used in mL, $M_{Na_2S_2O_3}$ is molarity of sodium thiosulfate ($Na_2S_2O_3$) and m is the weight of the sample in g. The p-anisidine value (PAV) was determined using the spectrophotometric method. Oil sample of 2 g was weighed and dissolved using 25 mL iso-octane. The absorbance of the solution was measured at 350 nm. A volume of 5 mL of this solution was added with 1 mL of 0.25% p-anisidine reagent. The mixture was stored in dark conditions at room temperature for 10 min. The absorbance of the mixture was measured at 350 nm. The PAV values of all samples were calculated as Eq. (2),

$$PAV = \frac{25 \times (1.2A - B)}{m} \quad (2)$$

where A is absorbance of the fat solution after reaction with the p-anisidine reagent and B is absorbance of fat solution before reaction with the p-anisidine reagent. Acid value (AV) was determined according to the AOAC method 940.28 [8]. Oil of 0.2 g was dissolved in 10 mL ethanol and titrated with 0.1 M potassium hydroxide solution using phenolphthalein as an indicator. The AV was calculated as Eq. (3).

$$AV = \frac{56 \times M_{KOH} \times V}{m} \quad (3)$$

where M_{KOH} is molarity of potassium hydroxide (KOH), and V is the titrated volume. Thiobarbituric acid (TBA) test was done according to Sae-Leaw et al. [9] with some modifications. Sample of 0.5 g was mixed with TBA solution (0.375% TBA, 15% trichloroacetic acid, 1.76 mL 12 N HCl and 82.9 mL distilled water). The mixture was heated between 95 and 100°C for 10 min and cooled under running tap water before centrifuging at 2000 g for 15 min. The supernatant was taken, and the absorbance was measured at 532 nm.

The fatty acid composition was determined according to [10]. Oil of 0.2 g was trans-esterified using 2 mL of 20% boron trifluoride-methanol (BF3) reagent and heated for 30 min. After the mixture was cooled, 2 mL of n-hexane and 8 mL of distilled water was added, and the mixture was mixed for 1 min. Then, it was centrifuged for 2 min at 2000 g. The upper layer of n-hexane was transferred to glass vials for analysis using GC 17 A-Shimadzu gas chromatography (Shimadzu Scientific Inc., USA) with the flame detector. The column used was BPX 70 (SGE, Australia) capillary column consisting of a 30 m $\times$ 0.32 mm fused silica capillary coated with 70% cyanopropylpolysilphenylene-siloxane of 0.25 µm film thickness. Fatty acid compositions were identified by comparing the retention times of the fatty acids methyl ester peak with standards. The fatty acid composition was expressed as percentages from total fatty acids and grouped as saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA).

E. Data Analyses: Descriptive Statistics, Cluster Analysis and Discriminant Functions

The SPSS software (version 12, IBM) was used to analyse the data. In addition to descriptive statistics, cluster analysis and discriminant analysis were also used to categorise the Muruku samples based on brands or types. Cluster analysis (CA) is a multivariate technique, whose primary purpose is to classify the objects of the system into categories or clusters based on their similarities. Cluster analysis (CA) is a multivariate technique, whose primary purpose is to classify the objects of the system into categories or clusters based on their similarities, and the main objective is to find similar observations and place them into one cluster (group) that are close to each other and are different to other clusters (groups). Clusters are formed sequentially which means that the most similar observations are first grouped to represent the clusters, and final step in cluster analysis is to be merged in one cluster as the similarity decreases. CA was commonly applied to quality and characteristics data using the single linkage method [11], [12].

Discriminant analysis is a multivariate technique used for separate groups and to identify the relative contribution of each selected variable using a linear combination of selected variables to describe the differences between groups. Furthermore, Discriminant analysis can be used to predict or reassign the observations to different groups by using the linear or quadratic functions [11], [12]. These statistical techniques enabled the classification of Muruku from different brands or types into different groups to investigate the variation of Muruku quality commonly available in the market.

III. RESULTS AND DISCUSSION

Basic information of Muruku is listed in Table 1. The price range was large, i.e., USD0.0133 to USD0.0067 per gram between the samples. M2 (obtained from a market) was the cheapest and M1 (prepared fresh by the street vendor) was the most expensive. M1, M6, and M7 (opaque polypropylene/polyethylene bags) had different packaging types compared to M2, M3, M4 and M5 (transparent polypropylene). M6 had the most advanced packaging strategy (semi-metallised zip lock) that might be helpful in retarding oil oxidation during commercial storage. Only five out of seven samples disclosed its expiration dates. Nevertheless, all chemical analyses were conducted as soon as the samples arrived in the laboratory and before the expiration dates of the samples.

A. *Fat, Moisture Content, Fatty Acid Composition and Colour Value of Oil*

Descriptive statistics for selected parameters of Muruku samples are presented in Tables 2 to Table 4. Fat, moisture content and fatty acid composition of the oil extracted from the Muruku samples are presented in Table 2. The results showed that the range of the average fat and moisture content were 29.27% to 45.47% and 0.73% to 5.35%, respectively. The lowest average fat content was in M4, and the highest was in M6. For moisture content, the highest average value was for M5, and lowest was for M1. The high-fat content in fried Muruku could be due to oil absorption from the frying oil used during the deep frying process as the oil replaced the moisture that evaporated. In addition to the frying step, differences in average moisture content could be due to the different packaging types and storage conditions of the Muruku samples.

TABLE II
FAT CONTENT AND FATTY ACID COMPOSITION OF THE MURUKU SAMPLES

Parameters	Muruku Samples						
	M1	M2	M3	M4	M5	M6	M7
Fat (%)	31.83 ± 0.18	33.90 ± 0.05	31.00 ± 0.14	29.27 ± 0.19	35.08 ± 3.53	31.43 ± 0.10	45.27 ± 0.17
Moisture (%)	0.73 ± 0.12	2.73 ± 0.11	4.50 ± 0.28	4.04 ± 0.21	5.35 ± 0.16	3.84 ± 0.10	1.48 ± 0.12
Fatty acids (%)							
Saturated	44.53 ± 0.88	43.88 ± 0.66	46.47 ± 0.58	48.23 ± 0.45	37.88 ± 0.56	44.61 ± 0.04	42.60 ± 0.21
MUFA	39.28 ± 4.15	30.49 ± 0.28	39.59 ± 0.37	40.26 ± 0.39	27.65 ± 1.56	44.46 ± 0.03	43.38 ± 0.12
PUFA	10.93 ± 0.08	10.27 ± 0.13	10.93 ± 0.10	10.17 ± 0.10	7.67 ± 0.10	10.93 ± 0.05	14.03 ± 0.10

TABLE III
COLOUR VALUES OF OIL EXTRACTED FROM THE MURUKU SAMPLES

Parameters	Muruku Samples						
	M1	M2	M3	M4	M5	M6	M7
L*	85.11 ± 0.01	35.33 ± 0.03	63.28 ± 0.00	64.00 ± 0.00	70.40 ± 0.01	74.18 ± 0.01	65.36 ± 0.01
a*	2.21 ± 0.02	36.38 ± 1.11	32.22 ± 0.00	33.83 ± 0.01	40.44 ± 0.08	29.62 ± 0.03	22.79 ± 0.01
b*	66.05 ± 0.02	49.56 ± 0.06	104.05 ± 0.02	106.79 ± 0.04	119.85 ± 0.03	120.79 ± 0.05	92.97 ± 0.04

TABLE IV
QUALITY CHARACTERISTICS OF OIL EXTRACTED FROM MURUKU SAMPLES

Parameters	Samples	Mean ± Standard deviations	Minimum	Maximum
	M1	3.52 ± 0.25	3.24	3.73
	M2	10.27 ± 0.04	10.23	10.31
	M3	6.01 ± 0.03	5.98	6.03
Peroxide	M4	5.37 ± 0.18	5.26	5.58
(meq/kg)	M5	5.72 ± 0.15	5.57	5.86
	M6	6.72 ± 0.12	6.62	6.85
	M7	6.52 ± 0.20	6.30	6.68
	M1	14.04 ± 0.01	14.03	14.05
	M2	3.67 ± 0.02	3.66	3.69
	M3	8.38 ± 0.01	8.37	8.39
p-anisidine	M4	8.68 ± 0.02	8.66	8.70
	M5	5.17 ± 0.02	5.16	5.19
	M6	3.07 ± 0.13	2.95	3.21
	M7	10.79 ± 0.21	10.55	10.92
	M1	8.29 ± 1.61	6.63	9.85
	M2	15.73 ± 1.39	14.37	17.15
Acid value	M3	4.58 ± 0.39	4.29	5.02
(mg KOH/g)	M4	4.52 ± 0.47	4.03	4.96
	M5	3.71 ± 0.03	3.68	3.74
	M6	4.15 ± 0.11	4.07	4.27
	M7	6.18 ± 0.04	6.14	6.21
	M1	38.59 ± 3.54	35.10	42.17
	M2	21.07 ± 0.08	20.98	21.12

TBA value	M3	17.12 ± 0.70	16.35	17.71
(mg MAD eq/kg)	M4	2.42 ± 0.14	2.26	2.53
	M5	27.57 ± 0.16	27.48	27.75
	M6	4.78 ± 1.05	3.84	5.91
	M7	21.54 ± 1.65	19.64	22.53

The average percentage of saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids (or fatty acid composition) of all the oil extracted from the samples were around 37.88% to 48.23%, 27.65% to 44.46% and 7.67% to 14.03%, respectively. Although fatty acid composition can be used to predict the initial oxidation state under conditions of high temperature or long storage time after opening the package, it might not provide an accurate estimation of oxidative stability of oils [13]. Nevertheless, as different types of oil were used during frying for the different samples, different composition of fatty acids was present in the Muruku samples after frying and during storage. For example, palm oil is known to contain higher proportions of saturated and monounsaturated fatty acids (MUFA), but a lower proportion of polyunsaturated fatty acid (PUFA) compared to soybean [6]. From the labels of the samples, only M3, M4 and M7 stated the use of palm oil for frying. Vegetable oil that is rich in PUFA is less stable and easier to oxidise compared to oil rich in MUFA. MUFA can withstand oxidation and become less degraded during heating. The ratio of PUFA to SFA that is recommended to be considered healthy is below 0.4 [14]. The ratio of the Muruku samples falls within this range with values of 0.20 to 0.33.

B. Lipid Oxidation Indices of Oil

The primary product of lipid oxidation is peroxide while extended oxidation gives rise to secondary oxidation products such as aldehydes, ketones, epoxides, hydroxyl compounds, oligomers and polymers [18]. Hence, the peroxide value (PV) test is used to detect primary oxidation product whilst both p-anisidine (PAV) and thiobarbituric acid (TBA) tests are used to detect the secondary oxidation products. Formation of hydroperoxide during the frying process causes an increase of PV. High PV means high rancidity and the oxidative reaction were influenced by several factors such as storage time, cooking temperature and exposure to air [19]. However, PV values do not indicate the exact level of oxidation in the samples because of the instability of the hydroperoxide compound. Peroxide decomposes to malonaldehyde (MAD) and can be measured using the TBA test. High values of TBA can be caused by heating and oxidation processes and can make food more rancid.. Acid value (AV) measures free fatty acids (FFA) content in oil. It is one of the quality indicators of oil because high AV and FFA could contribute to hydrolysis of triacyglycerides during frying, which produces FFA with diacyglycerides. FFA plays a very important role in the aroma and flavour of the food, and also contributes to the organoleptic quality of foods.

The differences between different brands or types of Muruku with regards to its lipid oxidation indices could be due to differences in ingredients, frying practices, and packaging types. Quality of Muruku samples according to their lipid oxidation indices are shown in Table 4. The average PV, PAV, AV and TBA values for all samples ranged from 3.52 to 10.27 meq of O_2/kg, 3.67 to 14.04, 3.71 to 15.73 mg KOH/g and 2.42 to 38.59 mg MAD eq/kg, respectively. M2 (sample from a market) had the highest PV and AV whilst M1 (sample from the street vendor) showed the highest PAV and TBA values. Compared to other samples M1 and M2 can be considered as poor in terms of oil stability. M4 (sample from a market) had the lowest TBA. Nevertheless, other samples M3, M5, and M7 also showed high TBA values indicating that the oil in these samples was also unstable. The previous study by Jonnalagadda et al. [7] showed that Muruku sample had TBA value of 16.1 to 65.5 mg MAD/kg. Maximum TBA value is 5 mg MAD/kg, while fish may consume up to 8 mg malonaldehyde/kg [20]. The present study shows that only sample M4 and M6 were below the maximum level of TBA value. The present study shows that the average AV, which was used as an indicator for edibility of oil, ranged from 3.71 to 15.73 mg KOH/g. Previous studies reported that AV for palm kernel oil was 14.04 mg KOH/g [14], which supports that most of the Muruku samples were fried using palm oil. The samples M4 and M6 (one from a market using transparent polypropylene bag and the other using opaque polypropylene bag with a window) showed overall good values of lipid oxidation indices and could indicate that these samples used better quality oil or frying practices. Even so, a more conclusive finding can only be obtained through detailed statistical analyses.

C. Cluster and Discriminant Analyses of Muruku Chemical Analyses Parameters

It is desirable to identify similarities between samples by analysing their parameters. This cluster analysis (CA) of twelve parameters obtained from each sample is presented in Fig. 1. CA was able to group the seven types of Muruku samples into four groups: Group 1 is represented by M1, Group 2 is represented by M2, Group 3 is represented by M3 and M4, whilst Group 4 is represented by M5, M6, and M7. It is possible to suggest that the four groups of Muruku exhibited four different standards of qualities. Thus, quality parameters of samples in group 3 (M3 and M4) and group 4 (M5, M6, and M7) tend to show close similarity and less fluctuation from other types in the same group, even though each type behaved differently from other types in the same group. Also of interest is the M1 sample that was freshly prepared and thus, grouped separately from other samples. Differences in quality between groups could be attributed to interplay between practices of processing, choice of raw materials including frying oils, choice of packaging materials and technologies and storage conditions. In summary, CA showed the possibility of grouping all samples based on the twelve parameters measured from each sample to understand the behaviour of the different samples.
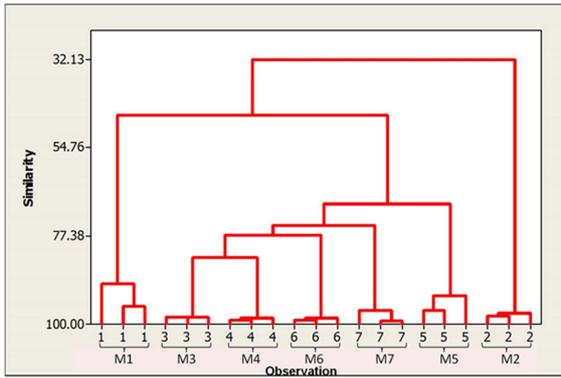
Fig. 1 Dendrogram showing clustering of Muruku for the different brands; the same numbers showed triplicate of each sample

Discriminant analysis (DA) was also carried out on the twelve parameters. Six discriminant functions (DF) were found to discriminate the seven samples as shown below, Eq. 4 to Eq.7.

$$DF1 \tag{4}$$
$$= -0.05\,MC + 2.64\,L* + 1.66\,a* - 0.56\,b* + 0.53\,PAV + 0.62\,TBA - 0.70\,SFA$$

$$DF2 \tag{5}$$
$$= -0.34\,MC - 0.29\,L* + 0.35\,a* + 1.53\,b* - 0.86\,PAV - 0.10\,TBA - 0.11\,SFA$$

$$DF3 \tag{6}$$
$$= -0.30\,MC - 0.04\,L* - 0.22\,a* + 0.50\,b* + 0.98\,PAV - 0.01\,TBA - 0.09\,SFA$$

$$DF4 = \tag{7}$$
$$+0.76\,MC + 0.02\,L* + 0.85\,a* - 0.34\,b* + 0.14\,PAV + 0.63\,TBA + 0.41\,SFA \tag{8}$$

$$DF5 = +0.45\,MC + 0.01\,L* + 0.21\,a* - 0.02\,b* - 0.01\,PAV - 0.35\,TBA + 0.92\,SFA \tag{9}$$

$$DF6$$
$$= +0.49\,MC - 0.06\,L* - 0.62\,a* - 0.02\,b* - 0.06\,PAV + 0.67\,TBA + 0.24\,SFA$$

Out of the twelve parameters, only seven parameters contribute significantly in explaining the differences between samples of different types. Wilk's Lambda test showed that DFs are statistically significant at $p < 0.0001$. The relative contribution of each parameter is represented by the coefficient associated with each parameter (DF1-DF6). It can be seen that the differences between different samples were explained by six DFs. The explanation of each DF depends on the magnitude of each coefficient in the DF as follows: the parameters L*, a*, b*, PAV, TBA, and SFA contribute greatly to the first function which explains the highest amount of variance between different samples. The relative contribution for different parameters can be arranged in the order L* > a* > SFA > TBA > b* > PAV (DF1 – DF6). Furthermore, the DF2 contributes less in explaining the differences by the parameters b* and PV (b* > PAV) whilst other parameters contribute less. Other DFs can be interpreted in a similar way.

An attempt was also made to study the relationship between the scores (the value of DF for each sample) of DFs (y-axis) and the samples (x-axis) that correspond to the scores of discriminant function for various samples, as shown in Fig. 2. It can be seen clearly in Fig. 2 that the samples were different based on the DA scores. Some samples showed positive contributions that was due to high values of L*, a*, PAV, and TBA, whilst negative contribution was attributed to high values of SFA and b* values. Moisture content did not contribute highly to DF1. The result of the first DF is similar to the cluster analysis grouping. The classification matrix (though not presented here) showed that 100% of the cases were correctly classified to their respective sources or markets/stores/vendors. The result of classification showed that significant differences exhibited between different markets, which are expressed in terms of DFs.
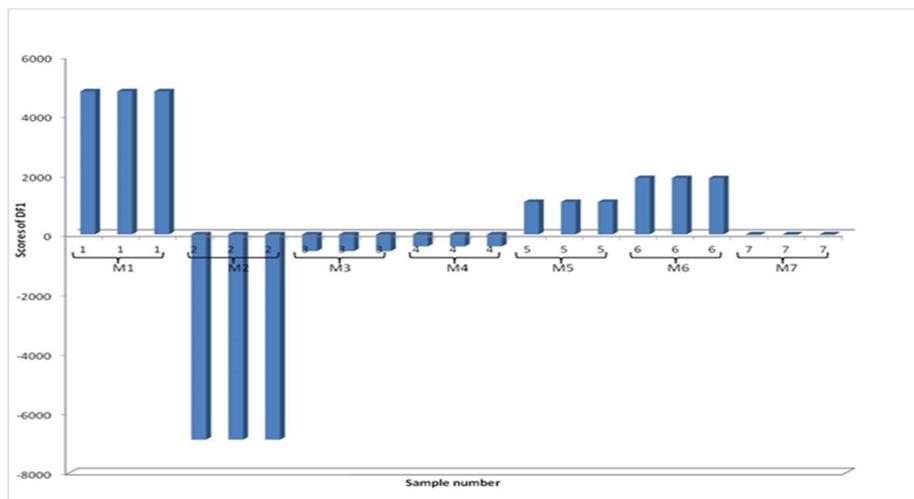
Fig. 2 Scores for the first discriminant function (DF1)

2284

Other than causing deterioration in nutritional quality, oxidative rancidity may give rise to unsafe food for consumption because highly oxidised oils or fats in food product might pose toxicity risk. The present investigation on seven different types of Muruku samples showed different chemical and physical parameters indicating differences in quality of fried snacks as a result of processing and storage. Raw materials and ingredients used in those samples were different as some might have antioxidative effects such as spices like cumin and caraway, which can also influence the shade or color of the Muruku. The antioxidant can delay the development of rancidity in food systems, so it will lower down the oxidative rancidity in food product [21].

PV of frying oil is considered rancid when the peroxide value is above 10 meq O_2/kg, PAV value more than 6.0 and AV is higher than 4.98 [22]. The present study indicated that PV of M1 was higher than the recommended value. As for PAV, only M2, M5, and M6 were within the recommended range. M3, M4, M5, and M6 were lower than the maximum limit for AV but for TBA value, only sample M4 and M6 fell within the recommended value. Hence, M6 had the highest quality characteristics compared with the other sources as M6 possibly strategised well in terms of quality of oil used and choice of packaging technologies (opaque bag with a window).

IV. Conclusions

Based on the chemical and statistical analyses conducted of food quality parameters, it can be said that the quality of the Muruku snacks was different between types or brands as shown by Cluster Analysis. Discriminant Analysis showed that the quality characteristics studied i.e., lightness values, saturated fatty acid contents, thiobarbituric acid, p-anisidine value and moisture content are the main contributors to discriminating the samples, indicating that most of the Muruku were subjected secondary oxidation either due to long storage or exposure to light and heat, which may increase the risk of rancidity. This can be avoided by using opaque packaging. The oil oxidation process was likely accelerated since the common food processing practices were to reuse the cooking oil. Types of frying oil used, processing practices, packaging technology, and storage conditions played some roles in controlling the final quality of the Muruku snacks. However, packaging technology might be the most important factor in producing a Muruku product with desirable food quality characteristics.

References

[1] Für Fettwissenschaft, D. G. Optimum Deep-Frying. Frankfurt, Germany. 2012.

[2] Ammawath, W., Che Man, Y. B., Yusof, S. and Rahman R. A. Effects of Type of Packaging Material on Physicochemical and Sensory Characteristics of Deep Fried Banana Chips. Journal of Food Science and Agriculture. 82: 1621-1627. 2002.

[3] Tiwari, U., Gunasekaran, M., Jaganmohan, R., Alagusundaram, K., and Tiwari, B.K. Quality Characteristic and Shelf Life Studies of Deep-Fried Snack Prepared from Rice Brokens and Legumes By-product. Food and Bioprocess Technology. 4(7): 1172–1178. 2011.

[4] Belayneh, M., Workneh, T.S., and Belew, D. Physicochemical and Sensory Evaluation of Some Cooking Banana (Musa spp.) for Boiling and Frying process. Journal of Food Science and Technology, 51(12): 3635–3646. 2013.

[5] Mariana, R.R., Kirana, T.M., and Hidayati, L. Analysis on the Quality Change of Tempeh, Catfish and Fried Chicken as the Effect of the Repetitive Used Cooking Oil. Journal of Food Research, 3(1): 96–104. 2014.

[6] Kamisah, Y., Shamil, S., Nabillah, M.J., Kong, S.Y., Hamizah, N.A.S., Qodriyah, H.M.S., Nur Azlina, M.F., Azman, A. and Jaarin, K. Deep-fried Keropok Lekors Increase Oxidative Instability in Cooking Oils. Malaysian Journal of Medical Sciences, 19(4): 58–63. 2012.

[7] Jonnalagadda, P.R., Bhat, R.V., Sudershan, R.V., & Nadamuni Naidu, A. Suitability of Chemical Parameters in Setting Quality Standards For Deep-Fried Snacks. Food Quality and Preference, 12(4), 223–228. 2001.

[8] AOAC. (2000). Official methods of analysis of AOAC International 17th Edition. AOAC International, USA.

[9] Sae-Leaw, T., S. Benjakul, N. Gokoglu and S. Nalinanon. Changes in Lipids and fishy Odour Development in Skin from Nile Tilapia (Oreochromis niloticus) Stored in Ice. Food Chemistry, 141(3): 2466-2472. 2013.

[10] Abdulhameed, A.A., Zzamam, W., and Yang, T.A. Application of Superheated Steam in Sample Preparation (Chicken Sausage) for Determination of Total Fat, Fatty Acid and Lipid Oxidation. Food Science and Technology, 2(3): 27–33. 2014.

[11] Johnson, R.A. and Wichern, D.W. Applied Multivariate Statistical Analysis, Prentice-Hall, London. 2002.

[12] Alvin, C. R. Methods of Multivariate Analysis, John Wiley & Sons, Inc., USA. 2002.

[13] Yun, J.-M., and Surh, J.-H. Fatty Acid Composition as a Predictor for the Oxidation Stability of Korean Vegetable Oils with or without Induced Oxidative Stress. Preventive Nutrition and Food Science, 17(2): 158–165. 2012.

[14] Otemuyiwa, I. O., and Adewusi, S. R. A. Fatty acid, Carotenoid and Tocopherol Content of Some Fast Foods from a Nigerian Eatery. Journal of Food and Nutrition Research, 1(5): 82–86. 2013.

[15] Bordin, K., Kunitake, M.T., Aracava, K.K., and Trindade, C.S.F. Changes in Food Caused by Deep Fat Frying - A Review. Archivos Latinoamericanos de Nutricion, 63(1): 5–13. 2013.

[16] Velasco, J., Dobarganes, C., and Márquez-Ruiz, G. Variables Affecting Lipid Oxidation in Dried Microencapsulated Oils. Grasas Y Aceites, 54(3): 304–314. 2003.

[17] Choe, E., and Min, D. B. Chemistry of deep-fat frying oils. Journal of Food Science, 72(5): 77-86. 2007.

[18] Barriuso, B., Astiasarán, I., and Ansorena, D. A Review of Analytical Methods Measuring Lipid Oxidation Status in Foods: A Challenging Task. European Food Research and Technology, 236(1): 1–15. 2013.

[19] Siddique, B.M., Ahmad, A., Hakimi Ibrahim, M., Hena, S., Rafatullah, M., and Omar A. K. M. Physico-chemical properties of blends of palm olein with other vegetable oils. Grasas Y Aceites, 61(4): 423–429. 2010.

[20] Duyar, H.A., and Eke, E. Production and Quality Determination of Marinade from Different Fish Species. Journal of Animal and Veterinary Advances, 8(2): 270-275. 2009.

[21] Martinez-Tome, M., Jimenez, A.M, Ruggieri, S., Frega, N., Strabbioli, R. and Murcia, M.A. Antioxidant Properties of Mediterranean Spices Compared with Common Food Additives. Journal of Food Protection, 64(9): 1412-1419. 2001.

[22] Sebastian, A., Ghazani, S.M., and Marangoni, A. G. Quality and Safety of Frying Oils Used in Restaurants. Food Research International, 64, 420–423. 2014.