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Relationships Between Fat Deterioration Indices and Sensory Properties of Fried Product

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Abstract: The relationship between 5 organoleptic properties of potato chip quality (e.g. appearance, taste, odor, crispiness and overall acceptability) and 11 indices of physico-chemical end-point measures were studied for refined, bleached and deodorized RBD palm olein, over a period of 5 days of deep-fat frying. Taste attributes of fried potato chips produced the strongest correlations with chemical parameters of oil quality. The use of data derived from day 5 of frying produced significant ($P<0.05$) results for all sensory attributes of potato chips and cooking oil parameters examined. In particular, lipid thermo-oxidative decomposition products significantly ($P<0.05$) influenced the overall acceptability of fried product. Specifically, peroxide value and the absorbance measurement recorded at 268 nm were shown to be the best parameters for predicting different sensory characteristics of deep fat-fried potato chips. Nutritional quality of RBD, as evaluated by the C18:2/C16:0 ratio did not correlate well with sensory scores after day 1 of frying, but was significantly ($P<0.05$) correlated with changes in organoleptic quality following prolonged (e.g. 5 days frying) processing.

Key words: Deep-fat frying, fat deterioration indices, potato chips, RBD palm olein, sensory properties

Introduction

Deep-fat frying is a commonly used practice in the preparation and manufacture of foods. In convenience and restaurant derived foods, such as chicken, French fries and potato chips, deep fat-frying is commonly used. It has been estimated that more than 230 tons of edible fats and oils are used annually for the manufacture of potato chips in the United States alone (Chang ***et al.***, 1978).

In commercial deep-fat frying, the oil is continuously exposed to air and light for extended periods of temperatures approaching 180^0 C (Augustin and Berry, 1983). Under these conditions, both thermal and oxidative decompositions of oil occur (Yang ***et al.***, 1983). It is well established that these reactions result in rapid deteriorations of the frying oil which ultimately effect significantly the functional, sensory and nutritive values, as well as safety, of the derived fried food product (Che Man and Irwandi, 2000). Numerous studies have shown that lipid oxidation products not only influence the quality and safety of the oil (Izaki ***et al.***, 1984), but also affect the acceptability of the fried product (Jacobson 1991). In many of these studies, relationships between sensory and chemical parameters of frying oils have been reported (Idris ***et al.***, 1992; Augustin ***et al.***, 1987). There are however, very few studies that have examined the specific correlations between physicochemical analyses of a frying oil and the related sensory properties of the fried product. Idris ***et al.*** (1992), reported some correlations between overall quality ratings of palm olein with chemical changes of the oil that involved free fatty acids, peroxide value and anisidine value. Other workers have shown that frying oils with low quality will produce lower acceptability scores for sensory properties of deep fat-fried processed foods (Singh, 1995).

This study reports the relationships between 5 organoleptic characteristics of potato chips that were deep-fat fried for 5 consecutive days in refined, bleached and deodorized (RBD) palm olein with 11 specific indices of oil deterioration attributed to deep-fat frying processing.

Materials and Methods

Materials

RBD palm olein used in this study was obtained from a local refinery. Oleoresin rosemary (OR; ***Herbalox*** Brand, Type 0) and sage (OS; ***Herbalox*** seasoning, Type S-0) extracts, were donated by Kalsec Inc., USA (Gulf Chemical Sdn. Bhd., Selangor, Malaysia). Citric acid (CA, food grade) was supplied by Bumi Sains Sdn.Bhd, Selangor, Malaysia. Fresh potatoes of the same variety (Russed var.) used throughout the experiment and sodium chloride were purchased from a local supermarket. All reagents were of analytical grade and supplied by local suppliers.

Experimental Design

To obtain data of frying oil with wide range of values used for calculation of linear regression equations, the frying procedure was set using 15 different combinations of natural antioxidants (Table 1). The antioxidants were added into the RBD palm olein prior to frying at day 1 (Irwandi ***et al.***, 2000a).

Frying Experiment

Fresh potatoes were peeled by hand and sliced to a thickness of 1.5 mm before frying. The sliced potatoes were then soaked in a 2.5% NaCl solution for 5 min, filtered and dried using paper napkins before frying. OR, OS and CA were added into RBD palm olein just before frying. The addition of the antioxidants was performed once at the beginning of the study (Che Man ***et al.***, 2000; Irwandi ***et al.***, 2000b; Irwandi ***et al.***, 2000c).

Frying experiments were performed in two replicates, similar to that reported by Che Man and Irwandi (2000). Frying was conducted in batch fryers (Berto's, Model ELT 8B, Italy), with 3 kg of oil heated up to 60°C. The oil was then heated up to 180±5°C in 10 min. Frying was started 30 min after the temperature of the oil reached 180°C. One hundred grams of fresh sliced potato

Table 1: Combinations of Oleoresin Rosemary Extract, Sage Extract and Citric Acid Added into RBD[1] Palm Olein before Frying

Trial No.	Rosemary (%)	Sage (%)	Citric Acid (%)
1	0	0.1	0.05
2	0.1	0.05	0
3	0	0.1	0
4	0	0	0.05
5	0.1	0.1	0.05
6	0.05	0.1	0.025
7	0	0.05	0.025
8	0.05	0.05	0.05
9	0	0	0
10	0.1	0	0.025
11	0.1	0.1	0.025
12	0.05	0.1	0
13	0.05	0	0
14	0.1	0.05	0.05
15	0	0.05	0

[1]RBD=Refined, bleached and deodorized

were fried for 2.5 min and then the oil temperature was returned to 180°C within 30 min. There were 10 frying conducted every day for 5 consecutive days. No fresh oil was added during the frying. The fryers were left uncovered during the frying operations. For the physico-chemical analyses, 200 g oil at temperature 60°C was removed from the fryer at the end of each day, flushed with nitrogen gas and kept in a cold room at 5°C. Fryer lids were then replaced and the fryer was left overnight for continuation of the experiment the following day.

After frying, the potato chips were removed from the fryer and surplus oil was drained. Both the ninth and tenth batches of potato chips were taken each day, cooled, labeled and packaged in low-density polyethylene plastic bags for sensory evaluation. The evaluation was conducted on the same day the frying was conducted.

Sensory Evaluation

Hedonic sensory attributes evaluated in this study included acceptability in appearance, taste, odor, crispiness and overall acceptance of the potato chips (Larmond, 1977). All these attributes were evaluated using a 7-point scale (1=dislike extremely, 4=moderate, 7=like extremely) by 20 experienced panelists selected from staff and graduate students of the Faculty of Food Science and Biotechnology, Universiti Putra Malaysia. All panelists regularly participated in sensory evaluation and are also regular consumers of potato chips. Sensory evaluation procedures were explained to the panelists before testing commenced. Panelists were asked to read through the instructions and the questions on the sensory form and a consensus understanding of each descriptor chosen was ensured to avoid misinterpretation. All panelists were given time to ask for clarification of the sensory evaluation procedure when uncertain or unclear about the process. All analysis was conducted in triplicates.

Analyses of Oil

Peroxide value (PV), free fatty acid (FFA) and iodine value (IV) were all determined using PORIM test methods (PORIM 1995). The oil color was measured in a one-inch cell in a Lovibond Tintometer (Salibury, United Kingdom) (PORIM 1995). Viscosity was monitored by using a Brookfield viscometer (Stoughton, MA) (PORIM 1995). The oil polymer content was analyzed according to the method of Peled ***et al.*** (1975). The absorbances at 232 and 268 mm and the anisidine value (AnV) were obtained using IUPAC methods (IUPAC 1979). The fatty acid profile of the oil was determined by gas chromatography (Hewlett Packard gas chromatography Type 5890) as reported by Berry (1980) using a 15m X 0.53 mm capillary column and a flame ionization detector. The temperature of the column was 140°C, programmed to increase at 4°C/min to 200°C. The temperature of both the injector and detector was 250°C. Flow rates for carrier gas nitrogen, hydrogen and air were 65 mL min^{-1}, 44 mL min^{-1} and 440 mL min^{-1}, respectively. Each reported value represents the mean of three replicates.

Statistical analyses

Data from physico-chemical analyses of oil and sensory evaluation of potato chips were statistically analyzed by one-way analysis of variance procedure using a SAS (1989) software package to determine the effect of frying time on the oil and the fried product. Significant differences (P<0.05) between means were further determined by Duncan's multiple-range test. In addition, the SAS programme was also used to determine linear regression relationship between the oil data and sensory responses of potato chips.

Results and Discussion

The changes in panelist sensory scores of fried potato chips (Table 2) and the physico-chemical properties of RBD palm olein (Table 3), during 5 days of deep-fat frying have been reported previously from studies that examined the effects of natural antioxidants on sensory characteristics of fried potato chips (Irwandi ***et al.***, 1999) and oil composition (1Irwandi ***et al.***, 2000a; Irwandi ***et al.***, 2000d). What was not described or discussed from our former studies was the correlation between the inter-related parameters of oil quality and the acceptability of the processed product. For example, all sensory scores derived from descriptive analysis of potato chip appearance after deep-fried potato chips decreased significantly (P<0.05) from day 1 to day 5 of frying. The lack of significant differences in appearance ratings of fried potato chips over time of use of the frying oil, could be explained by the choice of the preference test used in this study. For example, in samples where fried products possessed darker colors as a result of exposure to oils for 5 days of frying, higher scores reflected an actual preference by some panelists, while others showed a different preference for lighter colour product which originated from samples exposed to a shorter period (e.g. one day) of deep-fat frying.

During the 5 days of frying, all chemical quality parameters derived from the RBD palm olein decreased (Table 3). Notable increases in PV, AnV, FFA, oil colour (e.g. redness and yellowness), polymer content, viscosity and the C18:2/C16:0 ratio were observed. Similarly, estimates of the degree of primary oxidation (e.g. absorbance readings at 323 nm) and the presence of diethylenic

Table 2: Effect of Oleoresin Rosemary Extracts, Sage Extracts and Citric Acid on Sensory Scores[a] of Potato Chips

	After 1-Day Frying					After 5-Day Frying				
Trial No.	Appearance	Taste	Odor	Crispiness	Overall Acceptability	Appearance	Taste	Odor	Crispiness	Overall Acceptability
1	5.2	5.7	4.9	4.3	4.9	5.0	4.4	4.0	4.0	4.6
2	5.0	6.0	5.0	5.0	5.7	5.1	5.2	4.7	5.2	5.4
3	5.1	5.6	4.9	4.6	4.4	5.1	4.3	4.4	4.3	4.1
4	5.2	5.2	4.7	3.5	3.9	4.5	3.7	3.4	3.7	3.9
5	4.3	5.8	4.8	4.9	5.5	5.0	5.1	4.6	5.1	5.2
6	5.0	6.1	4.8	5.3	5.8	5.3	5.4	5.0	5.4	5.6
7	5.4	5.7	5.3	4.8	5.5	5.2	4.8	4.6	4.8	5.4
8	5.0	6.2	5.2	5.4	5.7	5.6	5.5	5.1	5.5	5.3
9 (control)	5.0	5.2	4.8	3.8	4.3	4.5	3.8	3.5	3.8	3.8
10	5.0	5.8	5.0	5.6	5.3	5.2	4.9	5.5	4.9	4.9
11	4.4	5.9	4.7	5.8	5.6	5.2	5.4	5.6	5.4	5.0
12	4.9	6.0	5.0	5.0	5.4	5.4	5.2	4.7	5.2	5.1
13	5.2	5.5	5.1	4.6	5.1	4.9	4.9	4.4	4.7	4.8
14	5.0	5.8	4.9	4.4	5.0	5.1	4.6	4.2	4.9	4.7
15	5.5	5.5	4.7	4.5	5.0	5.0	4.7	4.2	4.6	4.8

[a] Mean of 20 Panelists

Table 3: Physico-Chemical Changes of RBD Palm Olein during Deep-Fat Frying

		Trial Number														
Parameter	Frying Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Anisidine	1	28.52	28.20	29.05	30.10	28.05	27.10	29.15	28.06	31.53	28.65	28.10	27.99	28.05	28.00	29.10
Value	5	47.58	45.22	48.00	52.22	44.08	42.23	48.10	44.10	54.97	47.71	45.77	46.10	47.85	43.88	48.25
Peroxide	1	5.05	4.44	5.21	6.04	4.50	4.32	4.82	4.70	6.55	4.81	4.55	4.39	4.55	4.23	5.00
value	5	6.52	6.24	6.91	10.89	6.24	6.14	6.83	6.20	11.70	6.41	6.29	6.35	6.60	6.10	7.11
(meq kg^{-1})																
Iodine Value	1	54.15	54.95	54.65	54.10	55.10	54.80	55.05	55.70	54.02	55.01	54.99	55.20	55.13	54.65	54.85
(g I_2/100 g oil)	5	45.22	46.10	44.20	41.92	46.22	47.21	44.22	46.11	41.88	45.10	45.57	45.44	45.00	47.10	43.78
Free Fatty	1	0.12	0.12	0.13	0.14	0.12	0.12	0.13	0.11	0.14	0.13	0.12	0.12	0.12	0.11	0.13
Acid (%)	5	0.41	0.36	0.43	0.49	0.34	0.33	0.42	0.33	0.52	0.40	0.36	0.36	0.42	0.34	0.43
Polymer	1	0.49	0.44	0.56	0.61	0.42	0.40	0.53	0.41	0.71	0.45	0.46	0.49	0.52	0.40	0.55
Content (%)	5	1.53	1.44	1.57	1.89	1.42	1.39	1.54	1.40	1.97	1.49	1.47	1.47	1.54	1.40	1.58
Red Color	1	1.10	1.07	1.10	1.10	1.08	1.10	1.10	1.05	1.10	1.10	1.10	1.08	1.10	1.05	1.10
	5	1.31	1.30	1.33	1.35	1.27	1.28	1.32	1.25	1.35	1.32	1.30	1.30	1.34	1.25	1.35
Yellow	1	12.90	12.75	12.95	13.08	13.05	12.80	13.10	13.15	13.15	12.95	12.95	12.90	12.85	12.95	12.90
Color	5	14.05	13.90	14.05	14.10	13.90	14.00	14.10	14.00	14.10	14.00	13.95	14.00	14.10	14.00	14.10
Viscosity	1	52.84	52.40	52.61	53.01	51.89	52.17	52.81	52.26	53.17	52.50	52.44	52.66	52.62	52.62	52.71
(centipoise)	5	61.02	59.22	61.10	65.95	58.21	58.44	61.10	59.04	66.40	60.70	59.87	60.10	60.90	58.50	62.00
$E^{1\%}_{1cm}$	1	2.65	2.46	2.80	3.82	2.44	2.50	2.72	2.48	3.91	2.62	2.62	2.67	2.71	2.45	2.93
at 232 nm	5	5.40	4.95	6.10	9.00	4.80	4.84	6.10	4.85	9.01	5.25	5.00	5.10	5.80	4.80	6.25
$E^{1\%}_{1cm}$	1	0.72	0.65	0.91	1.53	0.63	0.62	0.90	0.63	1.75	0.71	0.71	0.70	0.73	0.63	0.75
at 268 nm	5	1.56	1.41	1.70	2.05	1.38	1.37	1.65	1.38	2.08	1.50	1.49	1.50	1.62	1.37	1.70
C18:2/C16:0	1	0.207	0.215	0.207	0.201	0.217	0.215	0.207	0.214	0.190	0.206	0.211	0.209	0.209	0.212	0.207
Ratio	5	0.167	0.177	0.163	0.154	0.178	0.183	0.163	0.181	0.135	0.173	0.175	0.174	0.166	0.182	0.160

ketones (e.g. absorbance readings at 268nm), also indicated that the longer frying time resulted in marked changes in lipid oxidation. A decrease in IV also provided a good estimate of the gradual lipid deterioration rate of the frying oil over the 5 day period examined.

Relationship between Sensory Characteristics of Fried Potato Chip and Quality Parameters of Frying Oil

Assessment of sensory characteristics of processed potato chips and associated changes in physico-chemical parameters of RBD palm olein during frying was performed on a data collected from 15 different samples over a 5 day period of frying and analyzed by linear regression analysis. Higher probabilities of significant correlations between sensory scores and physico-chemical changes of the frying oil were found in samples processed with 5 day-old frying oil, compared to relatively fresh (e.g. 1 day old frying) oil. For example, the hedonic scores for overall acceptability collected from samples processed in the oil used for 5 days of frying , had a lower range of values (e.g. 3.8-5.6) than samples fried in the oil used for only one day (e.g. 4.3-5.8). Similar differences in the range of C18:2/C16:0 ratio values in the cooking oil, after 5 days of frying (range= 0.135-0.183), versus only 1 day of frying (range= 0.190-0.217) were observed.

Tables 4-8 show the different correlation coefficients, associated P-values and related equations for predicted relationships between sensory response of potato chips and quality parameters of the RBC palm olein. Linear regression equations are only presented for the significant ($P<0.05$) relationships. In general, highly significant ($P<0.01$) linear relationships were obtained between the appearance of fried samples and physico-chemical quality parameters for the RBD palm olein after day 5 of frying (Table 4). Of interest was the finding that the correlation between potato chip appearance and viscosity changes of the frying oil were only significantly correlated ($P<0.05$) when data in individual frying days 1 and 5 were assessed separately. In contrast, no correlations were obtained when the data was combined for all days of frying, thus signifying that correlations for changes in potato chip appearance and frying oil viscosity were both dependent on a critical number of frying procedures for the oil. This explanation identifies the importance of thermal oxidation reactions that carry on sufficiently long enough to produce polymerization products that contribute to both increased viscosity of the frying oil and color changes of the fried product.

The significant correlations obtained between potato chip taste and the quality indices of the RBD palm olein used in frying (Table 5), support the findings of Idris ***et al.*** (1992), who also reported that flavor intensity scores of RBD palm olein were closely ($r= -0.92$) related to oil quality indices comprising of FFA, PV and AnV. In our study, the only exception to the significant correlations found between taste of fried potato chip and associated estimates oil composition changes occurred with the C18:2/C16:0 parameter obtained from oil that was used for only 1 day of frying. Deterioration of oils, common to the process of deep-fat frying, results in many thermally oxidative reaction products which in turn contribute to the flavor of the oil (Idris ***et al.***, 1992; Augustin ***et al.***, 1987). However, the findings of this study indicate that this is not necessarily an issue with oil that has undergone only 1 day of frying. Thus nutritional implications of deep-fat frying (e.g. stability of essential fatty acids such as C18:2) are not a concern with oil that has undergone thermal treatment for a relatively short period of time (e.g. 1 day). This

Table 4: Relationship between Appearance of Potato Chips and Quality Parameters of Palm Olein

Appearance vs.	Day	Correlation Coefficient, r	P Values	Equation
AnV	1	0.31	0.2723	
	5	-0.72	0.0005***	Y = -8.88X + 70.84
	Overall	-0.01	0.9581	
PV	1	0.27	0.3240	
	5	-0.84	0.0013**	Y = -4.91X + 32.00
	Overall	-0.27	0.1466	
IV	1	-0.23	0.4094	
	5	0.67	0.0017**	Y = 6.44X + 12.79
	Overall	-0.001	0.9941	
FFA	1	0.33	0.2329	
	5	-0.76	0.0002***	Y = -0.22X + 0.37
	Overall	-0.05	0.8117	
Polymer Content	1	0.39	0.1541	
	5	-0.74	0.0001***	Y = -0.22 X + 1.50
	Overall	0.06	0.9766	
Red Color	1	0.22	0.4229	
	5	0.67	0.0065**	Y = -0.08X + 1.70
	Overall	0.24	0.8990	
Yellow Color	1	-0.07	0.8039	
	5	-0.46	0.0883	
	Overall	0.07	0.7304	
Viscosity	1	0.60	0.0180*	Y = 0.62X + 49.48
	5	-0.80	0.0004***	Y = -6.71X + 94.96
	Overall	-0.09	0.6499	
Absorbance at 232 nm	1	0.28	0.3166	
	5	-0.83	0.0001***	Y = -3.97X + 25.98
	Overall	-0.17	0.3579	
Absorbance at 268 nm	1	0.21	0.4501	
	5	-0.81	0.0002***	Y = -0.63X + 4.80
	Overall	-0.02	0.8975	
C18:2/C16:0 Ratio	1	-0.16	0.5758	
	5	0.78	0.0005***	Y = 0.03X -0.01
	Overall	-0.09	0.6338	

*** highly significant (P<0.001); ** highly significant (P<0.01); * significant (P<0.05)

observation does not hold true for oil that was used for 5 frying periods. Since the final fat content of the potato chip approached 40% after frying (Guillaumin, 1988), changes in fatty acid content of the frying oil related to peroxidation and degradation reactions would contribute to the reduced taste acceptance scores of the processed potato chips.

Potato chip odor quality parameters were significantly (P<0.05) correlated with chemical changes in the frying oil for both short (1 day) and long (5 days) deep-fat frying periods. No correlations were obtained after only 1 day of frying (Table 6). Unlike the taste perception scores, these results indicate that oil deterioration of the frying oil was correlated less with odor perceptions of acceptance. Odors are primarily attributed to volatile substances which are perceived quickly by the olfactory sensory system. Thermal treatment of oil resulting in the

Table 5: Relationship between Taste of Potato Chips and Quality Parameters of Palm Olein

Taste vs.	Day	Correlation Coefficient, r	P Values	Equation
AnV	1	-0.83	0.0003***	Y = -2.96 X + 45.63
	5	-0.84	0.0019**	Y = -4.96 X + 70.83
	Overall	-0.85	0.0001***	Y = -12.73 X + 104.86
PV	1	-0.81	0.0003***	Y = -1.76 X + 14.98
	5	-0.81	0.0002***	Y = -2.54 X + 19.29
	Overall	-0.90	0.0001***	Y = -2.37 X + 18.45
IV	1	0.72	0.0026**	Y = 1.10 X + 48.52
	5	0.80	0.0003***	Y = 2.31 X + 15.08
	Overall	0.84	0.0001***	Y = 6.62 X + 15.08
FFA	1	-0.79	0.0004***	Y = -0.02 X + 0.26
	5	-0.87	0.0001***	Y = -0.09 X + 0.83
	Overall	-0.86	0.0001***	Y = -0.19 X + 1.27
Polymer Content	1	-0.87	0.0001***	Y = -0.26 X + 1.96
	5	-0.86	0.0001***	Y = -0.27 X + 2.81
	Overall	-0.86	0.0001***	Y = -0.72 X + 4.81
Red Color	1	-0.54	0.0001***	Y = -0.03 X + 13.94
	5	-0.64	0.0108*	Y = -0.04 X + 1.50
	Overall	-0.82	0.0001***	Y = -0.15 X + 1.96
Yellow Color	1	-0.45	0.0902	
	5	-0.65	0.0094**	Y = -0.17 X + 13.94
	Overall	-0.78	0.0001***	Y = -0.08 X + 14.42
Viscosity	1	-0.74	0.0016**	Y = -0.81 X + 57.24
	5	-0.84	0.0001***	Y = -3.73 X + 78.69
	Overall	-0.88	0.0001***	Y = -6.18 X + 89.64
Absorbance	1	-0.843	0.0001***	Y = -1.31 X + 10.28
at 232 nm	5	-0.86	0.0001***	Y = -2.15 X + 16.12
	Overall	-0.93	0.0001***	Y = -2.65 X + 18.25
Absorbance	1	-0.81	0.0001***	Y = -0.92 X + 6.13
at 268 nm	5	-0.86	0.0001***	Y = -0.35 X + 3.28
	Overall	-0.89	0.0001***	Y = -0.65 X + 4.64
C18:2/C16:0	1	0.16	0.5687	
Ratio	5	0.82	0.0002***	Y = 0.02 X + 0.08
	Overall	0.86	0.0001***	Y = 0.03 X + 0.03

*** highly significant (P<0.001); ** highly significant (P<0.01); * significant (P<0.05)

production of volatile oxidation products such as ketone, aldehydes or alcohols would be expected to be greater after 5 frying periods than after.

Significant (P<0.05) relationships were also obtained between texture parameters (e.g. crispiness scores of potato chips) and all of the different physico-chemical parameters of the RBD quality (Table 7). After 1 day of frying, potato chip crispiness was significantly (P<0.05) correlated with peroxide, anisidine and iodine values, as well as absorbance measurements taken at both 232 and 268 nm on days 1 and 5 of frying. Oil polymer content and viscosity character of the oil after both frequencies of frying were also correlated (P<0.05) with fried potato chip texture measurement (Table 7). These results indicate that textural changes in fried potato chips are more closely related to all parameters of oxidation and degradation of the cooking oil than

Table 6: Relationship between Odor of Potato Chips and Quality Parameters of Palm Olein

Odor vs.	Day	Correlation Coefficient, r	P Values	Equation
AnV	1	-0.20	0.4695	
	5	-0.66	0.0074**	Y = -3.44 X + 62.63
	Overall	-0.53	0.0026**	Y = -10.29 X + 86.48
PV	1	-0.22	0.4301	
	5	-0.74	0.0016**	Y = -2.00 X + 16.16
	Overall	-0.54	0.0022**	Y = -2.53 X + 17.95
IV	1	-0.31	0.2657	
	5	-0.73	0.0021**	Y = 1.63 X + 37.64
	Overall	-0.74	0.0001***	Y = 5.38 X + 24.52
FFA	1	0.56	0.0312*	Y = -0.02 X + 0.20
	5	0.64	0.0098**	Y = -0.07 X + 0.69
	Overall	0.52	0.0031**	Y = -0.16 X + 1.03
Polymer Content	1	-0.31	0.2603	
	5	-0.70	0.0034**	Y = -0.20 X + 2.45
	Overall	0.56	0.0012**	Y = -0.59 X + 3.80
Red Color	1	-0.31	0.4301	
	5	-0.47	0.0016**	Y = -0.03 X + 1.42
	Overall	-0.48	0.0022**	Y = -0.11 X + 1.73
Yellow Color	1	0.04	0.8790	
	5	-0.59	0.0216*	Y = -0.07 X + 14.32
	Overall	-0.44	0.0149*	Y = -0.49 X + 15.79
Viscosity	1	-0.06	0.8405	
	5	-0.70	0.0036**	Y = -2.72 X + 13.34
	Overall	-0.60	0.0004***	Y = -5.50 X + 82.66
Absorbance at 232 nm	1	-0.38	0.1625	
	5	-0.75	0.0012**	Y = -1.66 X + 13.34
	Overall	-0.70	0.0001***	Y = -2.59 X + 16.55
Absorbance at 268 nm	1	-0.29	0.3001	
	5	-0.73	0.0020**	Y = -0.26 X + 2.77
	Overall	-0.57	0.0001***	Y = -0.54 X + 3.78
C18:2/C16:0 Ratio	1	0.08	0.7706	
	5	0.70	0.0036**	Y = 0.01 X + 0.10
	Overall	0.61	0.0004***	Y = 0.03 X + 0.06

*** highly significant (P<0.001); ** highly significant (P<0.01); * significant (P<0.05)

the perception of taste and odor changes. As was the case with both the observed taste and odor qualities of the fried potato chips, indices of nutritional quality of the oil, such as the C18:2/C16:0 ratio, was found to correlate only to the textural changes of crispiness after day 5 of frying. Thus, a relationship between the nutritional quality of the cooking oil and textural changes of potato chips could only be predicted after repeat fryings of the oil.

Finally, the significant (P<0.05) relationships noted between the overall acceptability of potato chips and the physico-chemical characteristics of RBD palm olein during frying is given in Table 8. It is clear, that with exception to the yellow colour parameter of the oil, all RBD quality parameters were significantly (P<0.05) related to the overall hedonic acceptability scores for fried potato chips. After only 1 day of frying, a linear correlation (P<0.05) between overall

Table 7: Relationship between Crispiness of Potato Chips and Quality Parameters of Palm Olein

Crispiness vs.	Day	Correlation Coefficient, r	P Values	Equation
AnV	1	-0.69	0.0044**	Y = -1.16 X + 34.18
	5	-0.78	0.0006***	Y = -4.34 X + 67.60
	Overall	-0.20	0.2957	
PV	1	-0.71	0.0033**	Y = -0.72 X + 8.32
	5	-0.73	0.0022**	Y = -2.12 X + 17.14
	Overall	-0.51	0.0044**	Y = -1.44 X + 12.82
IV	1	0.76	0.0019**	Y = 0.55 X + 52.20
	5	0.73	0.0019**	Y = 1.98 X + 35.67
	Overall	0.18	0.3532	
FFA	1	-0.53	0.0404*	Y = -0.01 X + 0.16
	5	-0.83	0.0001***	Y = -0.08 X + 0.78
	Overall	-0.21	0.2707	
Polymer Content	1	-0.71	0.0030**	Y = -0.10 X -0.71
	5	-0.79	0.0005***	Y = -0.23 X -0.79
	Overall	-0.21	0.2727	
Red Color	1	-0.17	0.5463	
	5	-0.61	0.0158*	Y = -0.04 X + 1.48
	Overall	-0.13	0.4849	
Yellow Color	1	-0.36	0.1860	
	5	-0.67	0.0066**	Y = -0.08 X + 14.40
	Overall	-0.11	0.5581	
Viscosity	1	-0.71	0.0033**	Y = -0.54 X + 54.32
	5	-0.78	0.0005***	Y = -3.24 X + 76.15
	Overall	-0.26	0.1784	
Absorbance	1	-0.75	0.0013**	Y = -0.54 X + 5.38
at 232 nm	5	-0.78	0.0006***	Y = -1.83 X + 14.46
	Overall	-0.40	0.0282*	Y = -1.23 X + 10.14
Absorbance	1	-0.73	0.0021**	Y = -0.39 X + 2.70
at 268 nm	5	-0.80	0.0004***	Y = -0.31 X + 3.03
	Overall	-0.47	0.0084**	Y = -0.37 X + 2.98
C18:2/C16:0	1	-0.13	0.6455	
Ratio	5	0.77	0.0008***	Y = 0.02 X + 0.09
	Overall	0.22	0.2536	

*** highly significant ($P<0.001$); ** highly significant ($P<0.01$); * significant ($P<0.05$)

acceptability of fried product and most physico-chemical parameters, with exception to the C18:2/C16:0 ratio, was observed. This result confirms our other findings that nutritional quality of the oil, based on the essential fatty acid composition and sensory parameters are not directly related early on in the frying process of potatoes. A possible explanation for this observation , is the fact that potatoes represent a relatively low fat containing food and thus very little endogenous lipid would be released from the potatoes into the frying fat. As a consequence to this, endogenous lipids of the potatoes would have contributed little to the fatty acid composition of the RBD after only 1 day of frying. Changes in the essential fatty acid ratio after 5 days of frying therefore represent thermal oxidation and decomposition of the cooking oil and thus loss of nutritional value that corresponded to similar losses in hedonic scores. This

Table 8: Relationship between Overall Acceptability of Potato Chips and Quality Parameters of Palm Olein

Overall Acceptability vs.	Day	Correlation Coefficient, r	P Values	Equation
AnV	1	-0.77	0.0008***	Y = -1.44 X + 36.04
	5	-0.81	0.0002***	Y = -4.84 X + 70.50
	Overall	-0.43	0.0183*	Y = -7.26 X + 74.04
PV	1	-0.82	0.0002***	Y = -0.93 X + 9.66
	5	-0.78	0.0007***	Y = -2.45 X + 18.94
	Overall	-0.69	0.0001***	Y = -2.08 X + 16.35
IV	1	0.78	0.0007***	Y = 0.62 X + 51.64
	5	0.77	0.0008***	Y = 2.23 X + 34.20
	Overall	0.41	0.0263**	Y = 3.64 X + 31. 73
FFA	1	-0.68	0.0071**	Y = -0.01 X + 0.18
	5	-0.58	0.0410*	Y = -0.09 X + 0.81
	Overall	-0.43	0.0178*	Y = -0.11 X + 0.80
Polymer Content	1	-0.79	0.0007***	Y = -0.12 X + 1.12
	5	-0.52	0.0001***	Y = -0.26 X + 2.78
	Overall	-0.44	0.0150*	Y = -0.42 X + 3.13
Red Color	1	-0.34	0.2123	
	5	-0.60	0.0186*	Y = -0.04 X + 1.49
	Overall	-0.37	0.0446*	Y = -0.07 X + 1.57
Yellow Color	1	-0.43	0.1121	
	5	-0.55	0.0330*	Y = -0.07 X + 14.37
	Overall	-0.34	0.0671	
Viscosity	1	-0.74	0.0017**	Y = -0.42 X + 54.76
	5	-0.82	0.0002***	Y = -3.62 X + 78.34
	Overall	-0.48	0.0076**	Y = -3.80 X + 75.65
Absorbance at 232 nm	1	-0.82	0.0002***	Y = -0.66 X + 6.20
	5	-0.80	0.0004***	Y = -2.01 X + 15.56
	Overall	-0.60	0.0004***	Y = -1.95 X + 14.01
Absorbance at 268 nm	1	-0.79	0.0004***	Y = -0.47 X + 3.27
	5	-0.82	0.0002***	Y = -0.34 X + 3.23
	Overall	-0.67	0.0001***	Y = -0.56 X + 3.99
C 18:2/C 16:0 Ratio	1	0.27	0.3256	
	5	0.77	0.0007***	Y = 0.02 X + 0.08
	Overall	0.48	0.0070***	Y = 0.02 X + 0.09

*** highly significant (P<0.001); ** highly significant (P<0.01); * significant (P<0.05)

explanation may not hold true if for example the food source that was been fried was relatively rich in fat (e.g. sardines) and would have contributed endogenous lipid to the cooking oil. The significant correlations obtained between peroxide value (inverse linear {r= -0.69; P=0.001}) and absorbance measures at 268 nm (inverse linear {r=-0.67; P=0.0001}) with hedonic acceptance score, reflects changes in both primary and secondary stages of lipid oxidation, respectively.

In conclusion, results from this study indicate that significant correlations between 5 sensory attributes of potato chips and 11 physico-chemical quality parameters of the RBD palm olein existed with prolonged deep-fat frying. The data collected from day 5 of frying produced significant results for correlations between appearance, taste, odour, texture and overall acceptance for the processed potato chips and the physico-chemical quality estimates of the heat treated RBD palm olein. Lipid thermo-oxidative decomposition products, as indicated especially by peroxide value and absorbance changes at 268, were found to be good predictors of the acceptability of potato chips fried in this oil. The nutritional quality of the frying oil and the sensory scores of the processed potato chips were not related with 1 day frying oil, but did show a significant relationship with 5 day frying oil. We conclude from this observation, that changes in essential fatty acid composition of the thermally processed RBD palm olein are related closely to both oxidation and degradation of the oil and that these associated changes corresponded to reduce organoleptic quality of the fried product.

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