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Changes in Oxidative Stability and Fatty Acid Composition of Commercially Produced Chips During Shelf-Life

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Changes in oxidative stability and fatty acid composition of commercially produced potato and corn chips during shelf-life were studied. The chips were stored at ambient conditions for four months which was given by the manufacturers. At definite time intervals, the absorbed oil was extracted from the chips and analyzed for free fatty acids, peroxide value, rancimat induction time and fatty acid composition. Sensory analysis for rancid flavour was carried out by an expert panelist group using a hedonic scale. Changes in fatty acid composition throughout shelf-life of potato and corn chips were insignificant ($p > 0.05$). Even though significant differences were determined in free fatty acids, peroxide value and induction time values as well as sensory scores ($p < 0.05$), potato and corn chips maintained their oxidative and hydrolytic stability and rancid flavour was sensorial acceptable at the end of shelf-life.

Key Words: Chips, Fatty acids, Oxidative stability, Rancid flavour, Shelf-life.

INTRODUCTION

In snack foods, including potato and corn chips, frying oils play important functional and sensory roles. Therefore, the type of oil used to fry chips is a major concern. Various researches[1-10] have studied alternative frying oils as well as the effects of oil composition on chips quality and stability. Snack foods are particularly sensitive to rancidity due to their high oil and fat content (20-30 %), large surface area and porosity. In addition, long storage times (weeks to months) may be involved between preparation and consumption of the snack foods and therefore they can become rancid and unacceptable to consumers[10,11].

The objective of this study was to determine the changes in oxidative stability and fatty acid composition of commercially produced potato and corn chips throughout their shelf-life. Development of rancid flavour was also evaluated by a sensory panel.

EXPERIMENTAL

Commercially produced potato and corn chips were used in the experiments and provided from three different manufacturers. Chips samples of each manufacturer (commonly consumed nationally available brands) were coded with a letter (A,B,C) and they were taken for examination 3 times over a 2 month period. Shelf-life given by the manufacturers on the label was 4 months for all samples. In order to start the examination of the samples just at the beginning of their shelf-life, all samples were brought to laboratory within 1 to 3 d after the production date. The changes of free fatty acids, peroxide value, rancimat induction time and rancid flavour were determined at 0, 1, 2, 3 and 4 months and fatty acid composition at 0, 2 and 4 months. Samples were stored at ambient conditions throughout storage period in their original packages. Fatty acid methyl ester (FAME) standards (99% purity) were purchased from Nu Chek Preperations (Elysian, Minn., USA).

Extractions of the lipids: Lipid extraction from the samples was carried out by hexane extraction under the operating conditions specified in ICC Standard No. 136. Total fat contents of the samples are expressed as a percentage by mass of the product as received[12].

Preparation of fatty acid methyl esters: They were prepared from the fats after alkaline hydrolysis, followed by methylating in methanol with BF_3 as catalyst. The final concentration of the fatty acid methyl ester was *ca.* 7 mg/mL in heptane[13].

Capillary gas-liquid chromatography (GLC): Analyses of the fatty acid methyl ester by capillary GLC were carried out on a Hewlett-Packard 6890 chromatograph, equipped with a Chrompack Autosampler-M911 (Chrompack, Middelburg, The Netherlands) for split-type injection and a flame-ionization detector (FID). A fused-silica capillary column was used for the FAME analysis; CP™-Sil 88, 50 m × 0.25 mm i.d., 0.2 mm film; Chrompack. The column was operated isothermally at 177ºC, injection port and detector were kept at 250ºC. The carrier gas was helium at a flow rate of 1 mL/min; split ratio: 1:50, volume of injected sample: 1 µL.

Stability to oxidation (automated Swift Test with Rancimat): *Ca.* 2.5 g of fat was heated for 10 min at 120ºC in the rancimat heating block (679 Rancimat Instrument, Metrohm-Herisau, Switzerland). The dry air feed and the collection vessel were then connected. The measurement of the conductivity curve then started. The breaking point was equal to the induction time (h)[14]. Fat samples extracted from the chips were subjected to analysis for free fatty acids and peroxide value according to IUPAC methods no. 2.201 and 2.501, respectively[15].

Sensory evaluation: Sensory evaluation of chips samples for rancid flavour was conducted according to hedonic scale[11] at 0, 1, 2, 3 and 4 months and data were obtained from 6 expert panelists (0: bland, 1: suspicion of rancid flavour, 2: noticeable but very slight rancid flavour, 3: noticeable rancid flavour, 4: distinct rancid flavour, 5: disagreeable, unpleasant rancid flavour, 6: markedly disagreeable, very rancid flavour).

Statistical analysis: The analysis of variance and multiple range tests were done on the analytical data collected for three replications of each treatment. The analysis was carried out using MSTAT software program and the least square differences test was applied in case of high significance.

RESULTS AND DISCUSSION

Table-1 shows the changes in free fatty acids (FFA), peroxide value (PV) and rancimat induction time (IT) of commercially produced potato and corn chips during 4 months of storage-life. FFA and PV gradually increased in all samples as storage time increased and when the shelf-life was over, final FFA and PV changed between 0.50-0.61 % and 2.8-3.8 meqO_2/kg, respectively. Significant changes ($p < 0.05$) were obtained in FFA and PV values of the chips samples during storage. FFA content, resulting from the hydrolysis of triacylglycerol as well as further decomposition of hydroperoxides, is one of the most important indicators of frying oil deterioration[16]. FFA value can be influenced by the oxidation rate and the state of oil[17]. Primary oxidation products, such as peroxides, seem to dominate at least during the early stages of storage and their determination provides an estimation of the storage oxidation of the fried products[18]. Induction time (120ºC), which is correlated with stability under ambient storage conditions for a wide range of fats and oils[19-21] has changed significantly ($p < 0.05$) in all chips samples between 0 and 4 months (Table-1). When the shelf-life was over, the stability of oils extracted from potato chips samples were slightly higher than the oils of corn chips.

Total fat content of the samples ranged from 33.1% (A-potato) to 23.4% (C-corn) and potato chips contained higher amount of fat than corn chips (Table-2). The major fatty acids in all samples were $C_{16:0}$, $C_{18:0}$, $C_{18:1}$ and $C_{18:2}$ acids, while the remaining fatty acids were each 1 % or less in the samples. The content of total *trans* fatty acids could be considered low in all samples (between 0.9-1.1 %). The changes in fatty acid composition throughout shelf-life of potato and corn chips were insignificant ($p > 0.05$). In addition, the initial proportions of total unsaturated fatty acids and total saturated fatty acids of the samples ranged from 49.2% (B-potato) to 56.7% (C-potato) and 43.3% (C-potato) to 50.8% (B-potato), respectively and these contents slightly changed during storage ($p > 0.05$). A wide variety of oils are used in chips production including sunflower oil, soybean oil, cottonseed oil, canola oil, corn oil and palm oil. One of the most important criteria for the selection of appropriate oil for frying is its stability, which is related to fatty acid composition. Oils with high saturated fatty acid content present unique stability in frying applications[22]. As it's clear from Table-2 that total saturated fatty acid contents of all samples were considerably high and composed of nearly fifty percent of the total fatty acids (50.8 % in B-potato). This might be a reason for keeping the oxidative stability of the analyzed samples during shelf-life. The fatty acid composition of the chips samples is that typical of palm oil which is well known, commonly used for industrial deep frying and holds oxidative stability[23-25].

TABLE-1
FREE FATTY ACIDS, PEROXIDE VALUE, AND RANCIMAT INDUCTION TIME OF COMMERCIALLY PRODUCED CHIPS DURING SHELF LIFE[a]

	Samples	Storage Time (months)				
		0	1	2	3	4
Free fatty acids (%)	A-Potato	0.40 a	0.45 b	0.48bc	0.50 c	0.52 c
	B-Potato	0.45 a	0.48ab	0.50bc	0.53cd	0.55 d
	C-Potato	0.36 a	0.39ab	0.42bc	0.46cd	0.50 d
	A-Corn	0.48 a	0.50ab	0.52ab	0.53bc	0.56 c
	B-Corn	0.50 a	0.55bc	0.58cd	0.60 d	0.61 d
	C-Corn	0.43 a	0.45ab	0.48bc	0.50cd	0.53 d
Peroxide value ($meqO_2$/kg)	A-Potato	2.8 a	3.0ab	3.2bc	3.4 c	3.5 c
	B-Potato	2.2 a	2.3 a	2.5ab	2.6 b	2.8 b
	C-Potato	2.5 a	2.6ab	2.9bc	3.1cd	3.3 d
	A-Corn	3.2 a	3.4ab	3.6bc	3.7bc	3.8 c
	B-Corn	2.7 a	3.0 a	3.5 b	3.6 b	3.7 b
	C-Corn	2.1 a	2.2ab	2.5bc	2.7cd	3.0 d
Rancimat induction time (h) at 120ºC	A-Potato	5.85 a	5.68 a	5.45 b	5.22 c	5.05 c
	B-Potato	5.15 a	5.03 a	4.95ab	4.91 b	4.80 b
	C-Potato	4.52 a	4.44 a	4.36ab	4.23bc	4.15 c
	A-Corn	4.70 a	4.65ab	4.50 b	4.26 c	4.10 c
	B-Corn	3.70 a	3.54 a	3.35 b	3.15bc	3.01 c
	C-Corn	4.45 a	4.32ab	4.20bc	4.10cd	3.95 d

[a]Each value is an average of three determinations, and values in each line followed by the same letter are not significantly different ($p < 0.05$).

TABLE-2

CHANGES IN FATTY ACID COMPOSITION OF COMMERCIALLY PRODUCED CHIPS DURING SHELF-LIFE[a]

Fatty acids	Corn chips									Potato chips								
	A			B			C			A			B			C		
	0	2	4	0	2	4	0	2	4	0	2	4	0	2	4	0	2	4
Total fat (%)	26.5	-	-	24.1	-	-	23.4	-	-	33.1	-	-	30.4	-	-	31.9	-	-
$C_{16:0}$	37.7	38.0	38.0	37.3	37.4	37.5	40.3	40.3	40.4	39.0	39.1	39.4	43.3	43.4	43.5	36.9	37.0	37.0
$C_{18:0}$	4.2	4.4	4.5	4.3	4.7	4.9	4.7	4.8	4.8	4.2	4.4	4.4	6.2	6.5	6.7	4.5	4.8	4.9
Total $C_{18:1}$[b]	40.3	40.3	40.4	40.8	40.6	40.6	39.3	39.4	39.5	43.3	43.0	43.1	41.1	40.9	40.8	46.6	46.5	46.4
Total $C_{18:2}$[b]	15.5	15.1	14.9	14.9	14.8	14.5	13.4	13.2	13.1	11.2	11.1	10.9	7.3	7.1	7.0	9.5	9.3	9.2
Others[c]	2.3	2.2	2.2	2.7	2.5	2.5	2.3	2.3	2.2	2.3	2.4	2.2	2.1	2.1	2.0	2.5	2.4	2.5
TMUS	40.7	40.6	40.7	41.2	41.0	41.0	39.7	39.8	39.8	43.8	43.5	43.4	41.7	41.5	41.3	46.9	46.8	46.7
TPUS	15.7	15.2	15.0	15.2	14.9	14.6	13.7	13.5	13.4	11.5	11.4	11.1	7.5	7.3	7.2	9.8	9.5	9.4
TUS	56.4	55.8	55.7	56.4	55.9	55.6	53.4	53.3	53.2	55.3	54.9	54.5	49.2	48.8	48.5	56.7	56.3	56.1
TS	43.6	44.2	44.3	43.6	44.1	44.4	46.6	46.7	46.8	44.7	45.1	45.5	50.8	51.2	51.5	43.3	43.7	43.9
TT	1.0	1.1	1.0	1.1	1.0	1.1	1.1	1.1	1.1	1.0	0.9	0.9	1.0	1.0	0.9	1.0	1.0	1.0

[a]Each value is an average of three determinations, and expressed as wt % of total fatty acid methyl esters. TS, total saturated; TMUS, total monounsaturated; TPUS, total polyunsaturated; TUS, total unsaturated; TT, total *trans*.

[b]Total $C_{18:1}$ (or $C_{18:2}$) is the sum of all $C_{18:1}$ (or $C_{18:2}$), including the all-*cis* and total *trans* isomers.

[c] Sum of percentages of $C_{10:0}$, $C_{12:0}$, $C_{14:0}$, $C_{16:1}$, all-*cis* $C_{18:3}$, $C_{20:0}$, $C_{20:1}$, $C_{22:0}$ acids.

Sensory evaluation scores for rancid flavour of the chips samples are given in Table-3. At the end of shelf-life, changes in rancid flavour was significant ($p < 0.05$) in all samples compared with previous months (Table-3) and suspicion of rancid flavour was perceivable in only one sample (C-potato) and the other samples had noticeable but very slight rancid flavour. The oxidative and hydrolytic rancidity values for chips samples tended to support panelist data. After 4 months, sample C-potato with the highest $C_{18:1}$ content (45.6 %) had the lowest intensity of rancid flavour which agreed with those of Warner *et al.*[4]. Lower level of $C_{18:3}$ content (0.1-0.3 % of total fatty acids) in chips could be attributed to their good oxidative stability and low rancid flavor intensity at the end of shelf-life which confirms the results of Warner and Gupta[10].

TABLE-3
CHANGES IN RANCID FLAVOUR SCORES OF COMMERCIALLY PRODUCED CHIPS DURING SHELF-LIFE[a]

Samples	Storage time (months)				
	0	1	2	3	4
A-Potato	0a	0a	0a	1b	2c
B-Potato	0a	0a	0a	1b	2c
C-Potato	0a	0a	0a	0a	1b
A-Corn	0a	0a	0a	1b	2c
B-Corn	0a	0a	1a	1a	2b
C-Corn	0a	0a	0a	0a	2b

[a]Each value is an average of six panelists, and values in each line followed by the same letter are not significantly different ($p < 0.05$)

As conclusion, commercially produced potato and corn chips maintained their oxidative and hydrolytic stability and rancid flavour was sensorial acceptable at the end of shelf-life.

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