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Flavor, Color and Texture of Peanuts Treated with Hydrogen Peroxide[1]

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ABSTRACT

Treatment of aflatoxin-contaminated peanut kernels in 0.075% hydrogen peroxide for 1 min has been proposed to reduce aflatoxin contamination by 90%. The effect of hydrogen peroxide treatment on the flavor quality, texture and color was, therefore, investigated. Two hundred grams of peanuts were submerged in a solution containing 0, 0.075 or 0.225% hydrogen peroxide for 1 and 3 min. Treated peanuts were dried to 8-9% moisture, blanched and stored in plastic bags for 0, 1, 2 and 3 weeks at 39 C. Peak areas identified as hexanal increased with increasing hydrogen peroxide concentration, regardless of the treatment and storage time. No significant differences in peak areas identified as ethanol were observed after a 3-week storage time, regardless of the concentration of hydrogen peroxide and treatment time. Hydrogen peroxide treatment and storage of treated peanuts did not significantly affect the lightness (L), chroma (C) and texture of the treated peanuts. Furthermore, sensory analysis conducted on peanut brittle prepared from raw peanuts and peanuts treated with 0.075% hydrogen peroxide for 1 min showed no significant difference between the two samples evaluated.

Key Words: Peanut, hydrogen peroxide treatment, sensory qualities.

Peanuts (*Arachis hypogaea* L.) are characterized by high oil and protein contents, and a low carbohydrate and ash content (16). Because of the high digestible protein content (25.4-33.8%), peanuts provide an ideal source of protein in countries where protein from animal sources are scarce or expensive. The peanut industry, however, is faced with the problem of aflatoxin contamination in its crops. Effective methods to prevent, eliminate and detoxify the toxins therefore have to be identified.

Separation of aflatoxin-contaminated kernels from non-contaminated kernels using hydrogen peroxide treatment has been proposed (2). Studies revealed that treatment of an aflatoxin-contaminated lot in a 0.075% hydrogen peroxide solution for 1 min resulted in a 90% reduction of aflatoxin in the segregated fraction. The use of hydrogen peroxide in foods was first reported in 1883 (6). It has been used as a preservative for milk in tropical countries. In the U.S., the Food and Drug Administration permits the use of 0.05% hydrogen peroxide in milk intended for the manufacture of Cheddar and Swiss cheeses and in various commodities such as starches, instant tea, corn syrup and emulsifiers (4). Blanching using 5% H_2O_2 has also been reported (18). The oxygen generated from the decomposition of hydrogen peroxide by peanut catalase offers some advantages: it destroys co-existing germs or microbes and has a bleaching effect which gives treated peanuts a smooth surface and an attractive appearance.

Hydrogen peroxide, however, is not a very stable product and is readily decomposed into water and oxygen and, upon degradation may generate free radicals (8). Since peanuts also contain approximately 50% oil, the H_2O_2 treatment in conjunction with drying may promote formation of hydroperoxides. The alkyl peroxides formed in the presence of oxygen could activate the enzyme, lipoxygenase, and thus lead to the development of undesirable odors and flavors in peanuts. The presence of pentane and hexanal has been associated with oxidation due to lipoxygenase activity (19).

Because of the semi-perishable nature of peanuts, their quality after storage must be carefully monitored. Curing of peanuts at elevated temperatures (>35 C) has been reported to cause development of off-flavors. These off-flavors are often accompanied by an increase in concentration of alcohols and aldehydes, primarily ethanol and acetaldehyde (9). Assessment of ethanol content was therefore deemed an appropriate indicator of off-flavor formation during storage under reduced oxygen levels and elevated temperatures. This study was conducted to determine the effect of hydrogen peroxide treatment on the flavor, color and texture of peanuts stored at 39 C for up to 3 weeks.

Materials and Methods

Sample Preparation

Medium grade size sound peanut (*Arachis hypogaea* L. cv. Florunner) kernels obtained from McClesky Mills, Smithville, GA were used in this study. Two hundred grams peanuts were submerged for 1 and 3 min in a 1 L beaker containing 800 ml of 0, 0.075 or 0.225% hydrogen peroxide. The liquid was then decanted and peanuts were dried in a forced air oven (Model 4-148CY, American Instruments Co., Silver Springs, MD) at 39 C

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to 8-9% moisture. Moisture content was measured by the automatic volatility computer AVC-80 (CEM Corp., Indian Trail, NC) and initial moisture content of the untreated peanuts was 8.44 ± 0.68%. Total drying time was less than 6 h. Testae were manually removed from the peanuts which were then sealed in plastic bags and stored at 39 C. Flavor, texture and color of treated peanuts were evaluated against raw peanuts after 0, 1, 2 and 3 weeks of storage. Three replicate experiments were conducted at each concentration of hydrogen peroxide, treatment time and storage time combinations.

Determination of gas chromatographic profile

Peanuts were subjected to gas chromatographic analysis using the method of Young and Hovis (21), with the following modifications. Ten grams of peanuts treated at each combination of concentration of hydrogen peroxide solution, treatment time and storage time were ground using a rotary grinder. Each ground sample (1.5 g) was placed in a 5 mL reaction vial, sealed with a teflon-lined screw cap and incubated for 20 min in a heating block maintained at 120 C. Head-space gas (1 cc) was withdrawn using a gas-tight vacuum syringe and injected into a Hewlett Packard 5890A gas chromatograph containing a 1.8 M x 1 mm ID glass column packed with Porapak-P 80-100 mesh (Waters Chem. Corp., Milford, MA). Initial oven temperature of 120 C was then programmed to increase at a rate of 20 C/min to a final temperature of 200 C within 4 min. Injector and detector temperatures were set at 220 C. Carrier gas (N_2) flow was adjusted to approximately 32 kPa so that the retention time of hexanal was about 5.00 ± 0.04 min. Each run was completed within 8 min and peak areas of the volatile components were determined using a 3390A Hewlett Packard Integrator.

Chroma Evaluation

A Minolta CR-200 series Chroma meter (Minolta Camera Co., Ltd., Osaka, Japan) set against a yellow reference standard (L = 66.9; a = 0.316; b = 0.334) was used to measure the L, a and b values of individual peanut kernels. Twenty samples from three replicate experiments were measured and the psychometric color term chroma (C) was calculated from the a and b values using the formula $C = (a^2+b^2)^{1/2}$.

Texture

An Instron Universal Testing Machine (Model 1122, Instron, Inc., Canton, MA) fitted with a modified Warner-Bratzler type meat shear blade and a 500 kg capacity load cell was used for texture measurement. A modified meat shear cell (Model CW-1, Food Technology Corp., Reston, VA) with a triangular cut-out as described by Hung *et al.* (5) was operated at 50 mm/min and a chart speed of 100 mm/min. A single peanut kernel was tested in each analysis. Twenty replicates were done and maximum forces were recorded.

Sensory Evaluation

To evaluate whether differences exist between untreated and treated peanuts, a triangle test (11) was conducted on peanut brittle containing both types of peanuts. Peanuts treated with 0.075% hydrogen peroxide for 1 min were used in the preparation of peanut brittle. Peanut brittle was prepared immediately after hydrogen peroxide treatment using the procedure described by Woodroof (20) with some modifications. A semi-trained panel consisting of 27 staff and graduate students of the University of Georgia Center for Food Safety and Quality Enhancement, Griffin, GA participated in the sensory test. Samples were coded using three-digit random numbers. The samples, two identical and one different, were simultaneously presented to the panelists in white sample cups on a white plate. None of the samples was identified as the standard. Hydrogen peroxide treated and control samples were systematically varied so that each was presented in odd and identical sample positions an equal number of times (11). The judges were asked to determine which one of the three samples presented was different from the other two.

Statistical Analysis

Statistical analysis of data was performed using the Analysis of Variance (ANOVA) and Duncan's Multiple Range Test procedures of the Statistical Analysis System (13). The expanded statistical table (12) was used to estimate significance in the triangle test.

Results and Discussion

Gas chromatographic profiles revealed the presence of 9-11 volatile compounds in untreated and treated peanuts. The dominant peaks were identified tentatively as ethanol (RT = 0.98 ± 0.01 min) and hexanal (RT = 5.00 ± 0.04 min) based on the retention times of respective standards. Low levels of these two components is desirable because presence of high ethanol content is often accompanied by development of off-flavors in peanuts (17) and hexanal has been associated with the beany flavor (1, 10).

Areas of peaks tentatively identified as hexanal for the untreated peanuts and peanuts treated with various concentrations of hydrogen peroxide for 1 min and then stored at 39 C for 0, 1, 2 and 3 weeks are listed in Table 1. Regardless of the storage time, peak areas of treated peanut samples were greater than those of the untreated kernels. The largest area was generated from peanuts treated with 0.225% hydrogen peroxide. This suggests that a high concentration of hydrogen peroxide in the treatment solution would yield a product having a greater peak area, which indicates a large amount of hexanal. High hexanal content is undesirable because its presence indicates deterioration due to oxidation of unsaturated fatty acids by the enzyme lipoxygenase (7).

Table 1. Areas of a gas chromatographic peak tentatively identified as hexanal obtained from raw untreated peanuts and peanuts treated with hydrogen peroxide.

Treatment		Peak Area*			
	H_2O_2	Storage Period, Weeks			
Time	(%)	0	1	2	3
0	Untreated	9260 a	9497 a	8620 a	8487 a
1	0	12980 b	10002 a	11692 b	12828 b
	0.075	11053 b	14308 b	10400 b	12447 b
	0.225	21828 c	24471 c	23226 c	29611 c
3	0	13290 b	10058 a	12664 b	13011 b
	0.075	15578 c	14422 b	13287 b	14728 b
	0.225	29011 d	27848 c	23106 c	25307 c

*Value in the same column, within each treatment time (1 or 3 min) and compared with untreated peanuts (0 min), which are not followed by the same letter are significantly different ($P < 0.05$).

An increase in peak area tentatively identified as hexanal (Table 1) was observed to result from treatment of peanuts in water (0% hydrogen peroxide) for 1 min. However, the difference in values for peak areas between peanuts treated with 0% and 0.075% hydrogen peroxide for 1 min was not significant ($P \leq 0.05$) except after 1 week storage. This suggests that at a low hydrogen peroxide concentration, the additional drying step played a more significant role in increasing hexanal content than did the hydrogen peroxide treatment. Changes in hexanal content in peanuts treated with hydrogen peroxide for 3 min were similar to that of peanuts treated for 1 min. The difference between values for peanuts treated for 1 and 3 min was not significant. A significant increase in hexanal content was observed as the hydrogen peroxide concentration was increased from 0.075 to 0.225% for peanuts subjected to a treatment time of 3 min. The effect of the hydrogen peroxide concentration, however, was more pronounced in peanuts treated for 3 min compared to those treated for 1 min. Statistical analysis revealed that storage time did not have a significant effect on the hexanal content.

It is possible that the excess hydrogen peroxide caused

the generation of free radicals which promoted the formation of alkylperoxides. These alkylhydroperoxides complexes with the non-heme iron of the enzyme, and after subsequent electron transfer mechanisms, will eventually yield hydroperoxides (7). The higher levels of hexanal in the treated peanut sample at week 0 thus may be due to the combined effects of the hydrogen peroxide and the action of lipoxygenase.

Most lipoxygenase, however, undergos rapid self-inactivation as the reaction proceeds (7). This could probably account for the decrease in hexanal content observed from week 0 compared to week 1. Furthermore, lipoxygenase activity could be related to its location in the seed. Eriksson (3) found that in peas, the center has the highest lipoxygenase activity and the lowest was found in the skins. If this is the case, lipoxygenase activity in peanuts is likely to be low at the surface of the whole nuts. With the degradation of hydrogen peroxide and the self-inactivation of lipoxygenase, lipid oxidation may have been limited during storage of whole kernels.

Regardless of the treatment time, no significant difference in the area under the peaks tentatively identified as ethanol was observed as the hydrogen peroxide concentration of treatment solution was increased and after the 3-week storage (Table 2). This result indicates that the suggested hydrogen peroxide treatment (0.075% for 1 min) for peanuts with low aflatoxin content would not have an adverse effect on the flavor quality of peanuts due to ethanol over a 3-week accelerated storage period. In most cases, peak areas identified as ethanol, however, were highest during the first week of storage after which a decline was observed as storage time progressed. The reduction in peak area identified as ethanol suggests a decrease in ethanol content over the 3-week storage period. Loss of ethanol is desirable since a high ethanol content has been associated with poor flavor quality (14, 17). This reduction in peak area identified as ethanol may not necessary imply that a reduction in ethanol production occurred. It is possible that the loss of ethanol was primary due to volatilization or subsequent chemical reactions involving ethanol. Singleton *et al.* (15) have shown that conversion of aliphatic alcohols including ethanol to their corresponding aldehydes do occur in peanuts. The increase in peak area observed when peanuts were treated with water (control treatment) also suggests that the added drying step resulted in an increase in ethanol content. Additional drying, however, may not be necessary for a shorter treatment time because absorption of water is minimal (18).

No significant differences in lightness (L) and chroma (C)

Table 2. Areas of a gas chromatographic peak tentatively identified as ethanol obtained from raw untreated peanuts and peanuts treated with hydrogen peroxide.

Treatment		Peak Area*			
	H_2O_2	Storage Period, Weeks			
Time	(%)	0	1	2	3
0	Untreated	49474 b	45697 a	47478 a	42539 a
1	0	50161 b	46339 b	49578 b	41604 a
	0.075	38888 a	50486 b	46037 a	44569 a
	0.225	40988 a	69370 c	50143 b	40358 a
3	0	52308 b	60070 b	40364 a	42911 a
	0.075	40386 a	57739 b	44621 a	43903 a
	0.225	41692 a	58130 b	47439 a	47009 a

*Value in the same column, within each treatment time (1 or 3 min) and compared with untreated peanuts (0 min), which are not followed by the same letter are significantly different ($P < 0.05$).

Table 3. Color of raw peanuts and peanuts treated with various hydrogen peroxide concentration for 1 and 3 min stored over a 3-week period.*

Treatment		Lightness, L				Chroma, C			
	H_2O_2	Storage Period, Weeks				Storage Period, Weeks			
Time	(%)	0	1	2	3	0	1	2	3
0	Untreated	47.70	50.10	48.10	51.37	0.376	0.375	0.370	0.374
1	0	51.59	52.56	55.78	45.07	0.371	0.371	0.370	0.372
	0.075	51.95	47.32	46.65	52.55	0.375	0.370	0.379	0.372
	0.225	50.65	49.54	54.87	54.10	0.372	0.361	0.378	0.374
3	0	52.83	53.08	52.89	46.48	0.370	0.373	0.369	0.368
	0.075	55.01	52.61	51.24	52.78	0.366	0.371	0.371	0.375
	0.225	56.06	52.07	53.97	51.62	0.370	0.372	0.371	0.371

*Values reported are means of 20 replicates.

Table 4. Texture of peanuts as affected by treatment in hydrogen peroxide.*

Treatment		Maximum force, N			
	H_2O_2	Storage Period, Weeks			
Time	(%)	0	1	2	3
0	Untreated	2.40	2.43	2.81	2.50
1	0	2.51	2.33	2.55	2.50
	0.075	2.38	2.60	2.71	2.35
	0.225	2.71	2.65	2.40	2.81
3	0	2.41	2.65	2.65	2.80
	0.075	2.71	2.78	2.45	2.56
	0.225	2.65	2.53	2.60	2.75

*Values reported are means of 20 replicates.

were observed among samples of raw untreated peanuts and peanuts treated with various hydrogen peroxide concentrations for 1 and 3 min over a 3-week storage period (Table 3). This indicates that hydrogen peroxide treatment and storage at 39 C for 3 weeks did not affect the color of the treated peanuts.

Similar results were obtained when texture of untreated and treated peanuts was measured. No significant difference in texture was observed (Table 4). The maximum force required to cut the peanut ranged from 2.3 to 2.8 N.

Based on an expanded statistical table for estimating significance of a triangle test, a minimum of 19 correct responses is required to establish a significant difference ($P \leq 0.05$) between peanut brittle prepared from untreated peanuts and peanuts treated in 0.075% hydrogen peroxide solution for 1 min. However, only 14 correct responses were obtained from the sensory analysis of the two types of peanut brittle. This indicates, then, that the panelists were unable to detect a difference between the two products.

From the physicochemical characterization and sensory analysis of untreated and treated peanuts, it appears that treatment of peanuts in 0.075% hydrogen peroxide solution for 1 min does not affect the flavor, texture and color of treated peanuts. For peanuts containing high concentrations of aflatoxins, a longer treatment time may be necessary for separation of contaminated and sound kernels; however, hydrogen peroxide treatment may be administered prior to the roasting process to reduce the adverse effect of drying. The results of this study indicate that treatment with 0.075% hydrogen peroxide for 1 min or less will produce an acceptable and stable product, as no significant change in sensory quality parameters were detected after a 3-week accelerated storage study at 39 C.

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