Safety of Nuts Heat-Processed in Molten Hexitols

R.B. ALFIN-SLATER, P. WELLS and L. AFTERGOOD, School of Public Health, University of California, Los Angeles, California 90024 and D. MELNICK, Best Foods Research Center, CPC International Inc., Union, New Jersey 07083

ABSTRACT

A blend of hexitols, comprising 80 parts by weight of mannitol and 20 parts of sorbitol, has been used in place of a frying fat in roasting nuts. Even though physicochemical tests demonstrated no measurable deterioration of the hexitol components on continuing repetitive use, biological studies were carried out to establish the safety of the end product. The latter was the novel dry roasted peanut product; the control consisted of conventionally air roasted peanuts. Both products were ground to peanut butter consistency and then stabilized with added hydrogenated peanut oil to facilitate the feeding programs. Male and female rats were maintained on the two peanut products for four generations. It was found that rats subsisting on diets containing the regular peanut butter increased in weight at a somewhat greater rate than did those on the diet containing the special peanut product. Efficiency of food utilization was not adversely affected and overall weight gains were satisfactory. All rats appeared normal and healthy throughout the experiment. There was no morbidity and no diarrhea. Breeding performance was slightly better among those rats on the special peanut product diet. No pathology was observed at autopsy and there were no differences in organ weights among the rats on the two diets. Total liver lipid and liver cholesterol levels were somewhat higher among the control peanut butter-fed rats, as compared to those on the "special" peanut butter diet. On the basis of (a) published related studies involving biological evaluations of the control peanut butter diet vs. the same adequate diet but containing no peanut components and (b) the present findings, it is concluded that no unknown factors of a toxic nature are present in peanuts roasted in the molten hexitol blend.

INTRODUCTION

In 1958, Avera (1) proposed roasting of nuts in the nonfat medium of the melted hexitols, sorbitol or mannitol. These compounds melt at high temperatures—anhydrous sorbitol at 89-101 C, mannitol at 166-168 C—and set up without decomposition at lower temperatures. Thus these hexitols behave as solid fats but, unlike fats, are not susceptible to oxidative deterioration.

TABLE I

Composition of Test and Control Peanut Products

Component	Ground peanut product	
	Made with novel dry-roasted peanuts[a]	Regular peanut butter
Hexitol content		
Mannitol, %	4.8	0
Sorbitol, %	1.2	0
Added sugars, %	0	2.5
Added salt, %	1.5	1.2
Nonfat peanut solids, %	43.8	45.5
Protein content, % (N x 6.25)	27.6	28.6
Oil content, %	48.7	50.8
Total calories/100 g	606.3	627.6

[a]Special peanut butter.

Subsequently, Wells and Melnick (2) developed an effective process for the commercial production of novel dry-roasted nuts, based on the roasting of the nuts in a blend of the two hexitols. Dry roasted nuts such as peanuts have become very popular today because they are dry to the touch, have a more crisp texture and, being more resistant to oxidation, have a longer storage life than oil-roasted nuts. One of the disadvantages of conventional dry air-roasted nuts is lack of a distinctive true nut flavor at time of purchase. To compensate for this, certain spice blends have been developed to impart desired flavors, and these have been applied to the nuts in coatings of various types. The coatings have been starch-based or gum-based and have a serious disadvantage in that they flake off. The flakes collect as unsightly "fines" in the bottom of the container in which the coated nuts are stored. By using the hexitols as the roasting medium, a coating of the hexitols is provided that immobilizes the salt applied, and the coating will not flake off. It is essential, for reasons given (2), to use a blend of mannitol and sorbitol, preferably in 80:20 ratio, in the hexitol roasting of nuts on a repetitive commercial scale. In the case of peanuts, the pickup of the hexitols amounts to 6% by weight of the end product. The mild sweet note imparted to the roasted nuts is not only compatible with, but also accentuates, nut flavor, just as added sugars provide enhanced organoleptic appeal to peanut butter.

In a subsequent development, Cooper and associates (3) provided a more economical process for hexitol roasting of nuts. In addition, the improved method allows more flexibility with regard to hexitol pickup, is based upon the use of only "virgin" hexitols in the continuous short time, viz., 10 min., roasting operation and hence eliminates the need to reprocess for color improvement the spent hexitols that periodically accumulated in the earlier process. The end product now contains less of the same hexitol blend of 80 parts mannitol to 20 parts sorbitol—in the case of the peanuts, 3% rather than the 6% previously fixed by the mechanics of the earlier less-flexible process.

Mannitol and sorbitol are related to carbohydrates, occur naturally, and are permitted food additives. In relation to dextrose, they provide the same (sorbitol) or less calories (mannitol) per unit weight and are less readily absorbed from the gastrointestinal tract. For this reason, they were considered as having potential laxative effects. In the early proposals by the U.S. Food and Drug Administration (4), there was no need for any statements if mannitol was used as a food additive in the amount of less than 2.5 g per average serving. When used at that or higher levels, the label was expected to include the grams provided in the average

TABLE II

Composition of Diet Used

Component	Composition, %
Peanut product[a]	35.00
Ground whole wheat	43.50
Lactalbumin	5.06
Skim milk powder	15.00
Salt (NaCl)	1.00
Calcium carbonate	0.50
α-Tocopheryl acetate	0.04
Crystalets (vitamins A and D)	0.0015

[a]Regular peanut butter was used in diet of control group and special peanut butter in diets of experimental group.

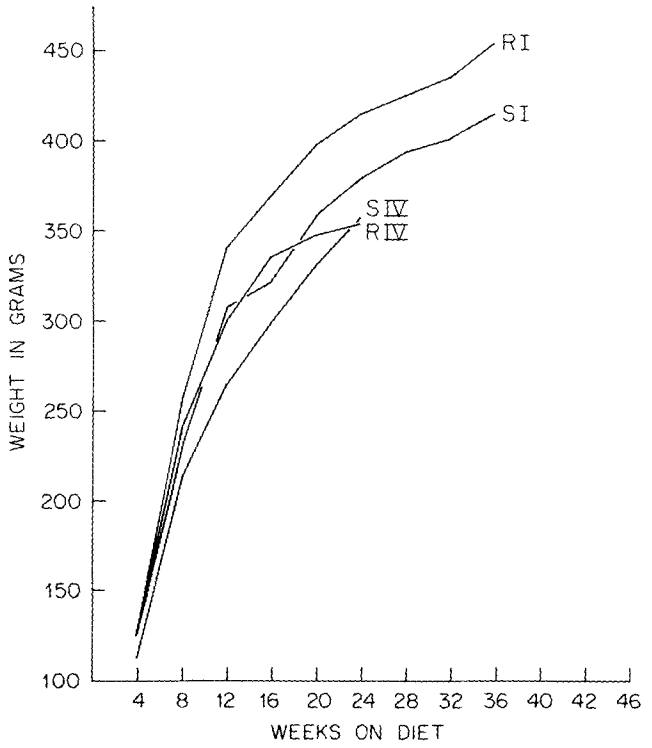

FIG. 1. Growth of first and fourth generations of male rats fed either regular (R) or special (S-mannitol-sorbitol processed) peanut butter diets.

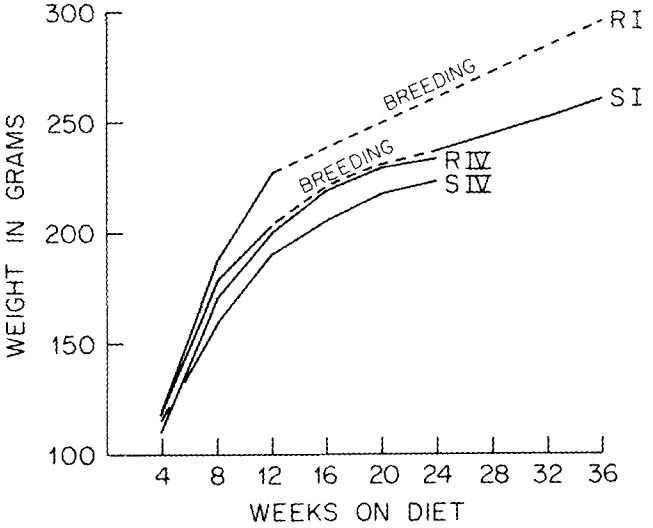

FIG. 2. Growth of first and fourth generations of female rats fed either regular (R) or special (S-mannitol-sorbitol processed) peanut butter diets.

serving and the cautionary statement that, "The consumption of more than 7.5 g of mannitol per day may have laxative effects." The regulation as it issued in 1963 concluded that there was no need for any special labeling for mannitol or cautionary statements with regard to potential laxative effects; the regulation (4,5) states, "The food additive mannitol may be safely used in food, provided that the amount used does not exceed that reasonably required to accomplish the intended physical or technical effect." There was always a greater tolerance for the use of sorbitol, and the final regulation for it reads the same as that quoted above for mannitol (4,6).

Whereas the above regulations cover the use of hexitols as direct food additives, they say nothing with regard to the hexitols when subjected to relatively high temperatures in processing, viz. 150-170 C. A commercial process based upon the use of the hexitols as a heat-exchange medium in cooking foods, resulting in some pickup of the heat-exchange medium by the food itself, was developed and probably was one of the first to emulate the use of frying oils in processing foods. However the hexitols are far more resistant to degradation changes, particularly in the presence of oxygen.

Since the earlier process (2) was far more drastic with regard to potential heat abuse of the hexitols and since the pickup of hexitols was greater in this earlier process, peanuts so processed provided the test products for evaluation in the present study.

PHYSICOCHEMICAL STUDIES OF HEATED HEXITOLS

These studies are reported in detail elsewhere (7). Crystalline sorbitol and mannitol, analyzed by gas chromatographic procedures before and after heat treatment of each, at ca. 170-180 C under air for 30 hr, gave data justifying the conclusion that within experimental error the small decrease in hexitol content corresponds to the increase in the hexitan content (0.17-1.8%). Furthermore there was no evidence of oxidative degradation products in any of the polyol samples analyzed. The same findings were obtained with the mannitol-sorbitol blends used in repetitive cooking of nuts at 160-165 F for total cooking times varying from 24 to 72 hr. Gas chromatographic techniques and differential scanning calorimetry were employed in these studies.

Despite the most thorough of physicochemical studies,

TABLE III

Comparison of Food Efficiency in Rats Fed Regular or Special Peanut Butter Diets

Group	Diet	Generation	Wt gain/day (ave.), g	Food eaten/day (ave.), g	Food efficiency[a]
Males	Regular	II(11)[b]	3.8	15.6	24.3 ± 6.7[c]
	Special	II(12)	3.2	13.7	23.4 ± 3.9
	Regular	III(12)	4.6	15.9	28.9 ± 6.0
	Special	III(10)	3.6	15.1	23.8 ± 1.9
	Regular	IV(12)	2.8	15.9	17.6 ± 4.2
	Special	IV(12)	4.4	14.3	30.8 ± 5.3
Females	Regular	II(15)	1.9	13.0	14.6 ± 4.3
	Special	II(19)	2.2	10.6	20.8 ± 4.7
	Regular	III(20)	2.5	13.1	19.1 ± 5.0
	Special	III(20)	1.8	13.0	13.8 ± 3.9
	Regular	IV(20)	1.4	12.2	11.5 ± 2.8
	Special	IV(19)	2.5	12.1	20.7 ± 5.2

[a](Wt [g] x 100)/(g food eaten).

[b]Number of animals studied.

[c]Includes standard deviation. This study was performed over period of 9-12 days at ca. 6 weeks of age.

TABLE IV

Summary of Breeding Data of Rats Fed Diets Containing Regular or Special (Mannitol-Sorbitol Processed) Peanut Butter in a Multigeneration Experiment

		Females		At birth		At 3 days			At 21 days	
Group	Generation	No. bred	Ave. wt, g	No. litters	Ave. no. rats/ litter	No. litters	Ave. no. rats/ litter	Ave. wt/rat, g	No. rats[a]	Ave. wt/rat, g
Regular	I	20	227	14[b]	5	9	5	8.0	43	41
Special	I	20	212	18[b]	6	11	6	8.3	58	36
Regular	II	19	216	17	10	15	9	7.5	104	39
Special	II	20	178	20	9	19	8	7.1	121	37
Regular	III	20	200	20	10	19	8	8.5	103	40
Special	III	20	217	20	11	19	10	8.2	124	38

[a]Breeding of first generation was hampered by the fact that animals in our colony were recovering from a respiratory infection (chronic) during reproduction and lactation. Thus first generation animals on both test diets were exposed to another physiological challenge, a common infection.

[b]Where possible litters were trimmed to seven pups each after 3 days.

there is always the possibility of some unknown toxic factor present in small concentrations escaping analytical detection. Biological studies are required to eliminate such possibilities before endorsing the product for human consumption. The present report presents such findings on a system involving far more heat abusive treatments (2) than that in current use (3).

BIOLOGICAL STUDIES

Batches of the novel dry-roasted peanuts were prepared according to the earlier process (2), with the hexitol blend having been in repetitive use over a 40 hr cooking period, with added hexitol blend replenishing that absorbed by the roasted peanuts. The roasted peanuts were converted to a uniform mass, to a peanut butter-type product, for inclusion in diets to be fed to the test animals. To 450 lb quantities of the dry-roasted peanuts in finely ground form and at 70 C was added 9 lb completely hydrogenated peanut oil. After thorough solution and dispersion of the latter, the blend was deaerated at 70 C, passed through a heat exchanger (Votator) to reduce the temperature to 27 C, passed through a working unit, and finally packed as 50 lb units under nitrogen in sealed pails. All product until time of use was stored at -5 to 5 C. The pertinent composition data for the test and control peanut products are listed in Table I. In the following, the test product will be referred to as the "special peanut butter," while the control will be referred to as the "regular peanut butter."

The diet contained the peanut butters at a level of 35%, and also contained protein, minerals and vitamins in amounts known to be required by the rat (Table II). The diets were fed to groups of 12 male and 24 female rats of the former USC strain for varying periods of time.

The experimental plan called for evaluations of growth responses (weight gains) on ad libitum feeding, appearance, reproduction and lactation performances and subsequent growth over four generations, observations on morbidity and mortality, measurements of food intake and calculations of efficiency of food utilization in consecutive generations. Examinations for gross pathology, measurements of organ weights and analyses of the plasma and liver for cholesterol and total lipid were also done on the rats in the first and fourth generations. Special attention was paid to the animals and their cages throughout the experimental period for possible evidence of diarrhea or other manifestations of morbidity.

RESULTS AND DISCUSSION

Figures 1 and 2, showing growth curves for the first and fourth generations, indicate that in generation I male and female rats consuming regular peanut butter had a slightly better weight gain than did those rats consuming special peanut butter. Part of this difference might be attributed to the somewhat higher caloric density of the regular peanut butter (Table I). (Weighing of the females was discontinued with the commencement of breeding at 10 weeks). In generation IV weight gain was comparable on both diets. Also, animals of the first generation had a higher weight gain that did their fourth generation counterparts, but differences in weight gain between experimental and control animals became minimal as the multigeneration experiment proceeded. In addition rats in all groups maintained a normal healthy appearance throughout the experimental periods.

Morbidity was minimal and nonspecific in all groups during the course of the experiment. Diarrhea was never observed at any time, and no significant differences in mortality between the groups were observed.

Table III summarizes average weight gain and food consumed over a period of ca. 10 days in both male and

TABLE V

Comparison of Gross Pathology Observed at Autopsy[a] of First and Fourth Generations of Rats Fed Either Regular or Special (Mannitol-Sorbitol Processed) Peanut Butters

Group	Generation	No. of rats examined	Liver	Adrenals	Testes/ ovaries	Kidney	Uterus	Mammary gland
Males								
Regular	I	12	0	0	2(16%)	0	---	---
Special	I	12	0	0	0	1(8%)	---	---
Regular	IV	6	0	0	0	0	---	---
Special	IV	12	0	0	0	0	---	---
Females								
Regular	I	14	0	0	0	1(7%)	2(14%)	0
Special	I	19	1(6%)	0	0	0	0	0
Regular	IV	10	0	0	0	0	0	0
Special	IV	19	0	0	0	0	0	0

[a]Expressed as number of rats with any type of abnormality in group.

female rats at ca. 6 weeks of age. Even with the data as erratic as they are, efficiency of food utilization is comparable among the animals on the two test diets. The overall weight gains, as reflected by the growth curves presented in Figures 1 and 2, indicate that these responses are satisfactory.

The findings in the present study relative to weight gains are of comparative value only, due to the relatively short periods of observations of the animals on the two diets. An earlier publication (8) has provided data on weight gains extended over much longer periods (52 and 104 weeks), when rats of the same colony were fed the same basic diet (identified as A_o in the early report) over four successive generations. Here also, ca. 50% of the calories were provided by the ground-roasted peanut component. The animals of the fourth generation showed the same good growth performance (weight gain) as those of the first generation. Other indices of biological adequacy, such as reproduction and lactation performance and survival, were maintained over consecutive generations and were also as good as those for the animals on the control adequate diet (C_o) containing no roasted peanut component.

Data on breeding, pregnancies and lactation are summarized in Table IV. Reproduction data in generations II and III were significantly improved over generation I and are comparable to what is usually achieved in our stock colony. The poor performance in generation I was due to a respiratory infection in our rat colony at the time. Breeding performance was slightly better among those rats on the special peanut product diet.

Animals of generations I and IV were continued on diets for 39 and 25 weeks, respectively. Gross pathology observed at autopsy is shown in Table V. No significant differences between the groups are apparent. Body and organ weights are summarized in Table VI. There were no consistently significant differences in organ weights, except for the larger pituitary gland in females of first generation fed the special peanut butter. Since this was not apparent in generation IV, it can be assumed that this is an artifact.

Results of lipid analysis of plasma and liver are presented in Table VII. Animals fed the regular peanut butter product show a trend to higher cholesterol and lipid levels in liver and lower cholesterol levels in plasma, than those fed the special peanut butter. In only one case, however, are the values of any significance—in liver cholesterol levels in males of generation IV. These values do not indicate the presence of a toxic component in the diet.

Comparison between the peanut butter diets and diets of similar composition derived from sources other than peanut butter that have been used extensively in this laboratory (8) revealed that the indices examined were similar in all cases. It is therefore concluded that incorporation of either the regular or special peanut butter at 35% of the diet into an otherwise adequate diet results in the satisfactory nutritional status of rats as determined by various nutritional, biochemical and histopathological analysis. No evidence of unknown toxic factors in either of these products has been observed. Inasmuch as the *more heat-abusive* test system (2) provided the mannitol-sorbitol (used in this study) processed peanuts, there is an even greater margin of safety in the case of the products in current commercial production by the improved process (3).

Pertinent to the above findings are practices in other industries, in which hexitols are heated for extended periods of time at temperatures considerably above those used processing nuts (2,3) without the formation of harmful degradation products (information supplied by Atlas Chemical Industries, Wilmington, Del.). Sugarless hard candies that contain sorbitol are heated to 200 C in their preparation. In the production of sorbitan monostearate, approved for use in a variety of foods, the sorbitol and fatty acids are reacted for several hours at temperatures of

TABLE VI

Body and Organ Weights of Male and Female Rats Fed Special (Mannitol-Sorbitol Processed) and Regular Peanut Butters for 39 or 25 Weeks

Group	Generation	Weeks on diet	% Surviving	Final body wt, g	Organ weights						
					Liver, g	Adrenal, mg	Kidney, g	Testes/ ovaries, g	Spleen, g	Heart, g	Pituitary, mg
Males											
Regular	I	39	100	457 ± 45	11.1 ± 1.1	39.4 ± 5.15	2.56 ± .22	3.26 ± .18	0.79 ± .08	1.50 ± .16	9.8 ± 1.2
Special	I	39	92	405 ± 51	10.5 ± .8	38.7 ± 4.5	2.36 ± .19	3.24 ± .19	0.67 ± .06	1.37 ± .12	10.1 ± 1.8
Regular	IV	25	100	356 ± 11	9.4 ± .5	38.5 ± 5.4	2.32 ± .06	3.00 ± .10	0.62 ± .05	1.30 ± .08	12.3 ± 3.3
Special	IV	25	100	355 ± 26	11.1 ± .8	42.7 ± 4.3	2.46 ± .15	3.09 ± .22	0.63 ± .08	1.26 ± .14	13.3 ± 1.7
Females											
Regular	I	39	95	292 ± 21	7.5 ± 1.4	53.7 ± 4.2	1.71 ± .21	57.9 ± 15.0	0.60 ± .08	1.02 ± .08	13.1 ± 2.5[a]
Special	I	39	90	267 ± 18	7.3 ± .8	55.1 ± 5.4	1.70 ± .15	37.4 ± 15.0	0.52 ± .06	1.01 ± .10	18.8 ± 2.2[a]
Regular	IV	25	83	236 ± 21	6.8 ± 1.0	55.2 ± 8.7	1.60 ± .10	65.0 ± 13.9	0.45 ± .05	0.92 ± .07	13.7 ± 4.9
Special	IV	25	100	227 ± 13	7.0 ± .9	50.8 ± 5.7	1.48 ± .12	58.1 ± 13.5	0.44 ± .04	0.82 ± .07	12.0 ± 1.8

[a]Matched superscripts indicate $p<.005$.

TABLE VII

Plasma and Liver Cholesterol and Total Lipids in Male and Female Rats Fed Regular and Special (Mannitol-Sorbitol Processed) Peanut Butter Diets for Either 39 (Generation I) or 25 (Generation IV) Weeks

Group	Generation	Cholesterol in plasma		Cholesterol in liver		
		Total, mg/100 ml	% Free	Total, mg/g	% Free	Total lipids in liver, mg/g
Males						
Regular	I	67.0 ± 6.9	27	2.47 ± .34	77	37.1 ± 10.5
Special	I	72.6 ± 8.0	26	1.84 ± .25	78	37.1 ± 7.9
Regular	IV	51.7 ± 5.6	23	2.32 ± .22[a]	87	48.2 ± 1.0
Special	IV	55.7 ± 10.0	24	1.86 ± .21[a]	85	44.1 ± 3.8
Females						
Regular	I	69.7 ± 8.6	27	1.99 ± .19	88	37.2 ± 7.4
Special	I	75.3 ± 7.8	28	1.78 ± .20	90	29.4 ± 7.4
Regular	IV	60.2 ± 5.6	23	2.11 ± .14	91	45.4 ± 2.1
Special	IV	63.4 ± 6.9	24	1.82 ± .10	87	42.0 ± 3.3

[a]Matched superscripts indicate $p<.005$.

220 C or even higher.

REFERENCES

1. Avera, F.L., U.S. Patent 2,859,121 (1958).
2. Wells, P.R., and D. Melnick, U.S. Patent 3,477,858 (1969).
3. Cooper, I., W.A. Parker and D. Melnick, U.S. Patent 3,671,266 (1972).
4. Hazleton Labs., Inc., and IFI Data Corp., Food and Color Additives Directory, Washington, D.C., 1961 (revised to June 1972), p. 1191, 1957.
5. Food Drug Cosmetic Law Reports, 21 CFR 121.1115, par. 56,015 (1967).
6. Food Drug Cosmetic Law Reports, 21 CRF 121.1056, par. 55,953 (1966).
7. Waltking, A., G. Bleffert, L. Brickman and P.R. Wells, JAOCS 50:353 (1973).
8. Alfin-Slater, R.B., L. Aftergood, H.J. Hernandez, E. Stern and D. Melnick, Ibid. 46:493 (1969).

[Received April 23, 1973]