

STUDIES ON THE ANTIGENICITY OF BANANA, RAW AND DEHYDRATED*

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BANANA, a common food in tropical areas, is increasing in use as a popular item in the diet of people everywhere. Furthermore, banana is being utilized as an important factor in the dietary management of many diseases, for example, celiac disease, sprue, and other derangements of the gastrointestinal tract.

In spite of the fact that it is extensively eaten, very little is known of its antigenicity. In routine cutaneous testing, positive reactions to banana are not infrequent.^{1, 2} Several authors have reported briefly on its etiology in acute urticaria,³ bronchial asthma,³ atopic eczema,^{4, 5} allergic rhinitis,^{6, 7} and gastrointestinal manifestations of allergy.⁸

Therefore, it seemed worth while to investigate the antigenic properties of this food. Extracts of raw, ripe banana and of commercially prepared dehydrated ripe banana were studied to determine their antigenicity in guinea pigs, and their allergenic properties in patients clinically sensitive to banana.

MATERIALS

Preparation of Extract of Fresh Banana.—The extracts used in these experiments were similar to those employed for routine intracutaneous testing in sensitive patients.

Seven ripe, 6-inch bananas (*Musa sapientum*) weighing 770 grams were mashed in a mortar and extracted under toluol at room temperature with 700 ml. of buffered saline solution. After 8 days, the uppermost brown-black layer and the toluol were discarded. The remaining substances were strained through gauze, filtered through paper, and passed through a Seitz filter. The clear, yellow-gray, sterile filtrate contained 0.53 mg. of nitrogen per ml., as determined by the macro-Kjeldahl method. This preparation was labeled B10.

Banana extract B11 was prepared in a similar fashion to B10 and contained 0.41 mg. of nitrogen per ml.

Preparation of Extract of Dehydrated Banana.—Fifty-seven Gm. of dehydrated banana,‡ representing 7 6-inch bananas (*Musa cavendishii*), were extracted with 700 ml. of buffered saline solution under toluol at room tem-

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‡The dehydrated banana used in these experiments is a canned preparation known as Kanana Banana Flakes, manufactured by Kannengiesser & Co., New York, N. Y. It is pure banana, processed to reduce moisture content with little loss of the nutritional and palatable properties of the original fruit.

According to information provided by the manufacturer, it is prepared as follows: The washed and peeled banana is reduced to a pulp and fed onto a revolving drum which is heated to approximately 103° C. Dehydration occurs in about 20 seconds. In some instances the process is shortened to 3 seconds at approximately 120° C. The resultant thin sheet is broken into flakes. The degree of heat used is just below that which would damage the vitamins or esters, caramelize the sugar, or affect color.

perature. On the eighth day, the toluol was discarded and the extract passed through paper and a Seitz filter. The sterile, yellow-green, clear filtrate contained 0.48 mg. of nitrogen per ml. and was labeled DB2.

Dehydrated banana extract DB3 was prepared in a similar fashion to DB2 and contained 0.41 mg. of nitrogen per ml.

A dialyzed extract was also prepared from defatted, dehydrated banana as follows: Fifty-seven Gm. of dehydrated banana were washed with ether, dried and ground to a fine powder. This was extracted under toluol at room temperature with 200 ml. of buffered saline solution. On the eighth day, the toluol was discarded and the remaining substances filtered through paper. The filtrate was dialyzed against physiologic saline solution for 3 days and then passed through a Seitz filter. The filtrate contained 0.37 mg. of nitrogen, and was labeled DB1.

EXPERIMENTS

Guinea pigs, weighing 195 to 430 grams, which had never been fed banana, were used in these experiments. Each animal was given a single intraperitoneal injection of extract for sensitization, and approximately 3 weeks later, an intracardiac injection for shocking purposes. After 4 to 16 days, those surviving this first intracardiac injection were then injected with the other extracts, as described below. Those succumbing were autopsied.

Series I.—Eleven guinea pigs were injected intraperitoneally with 3 to 5 ml. (1.23 to 2.12 mg. nitrogen) of banana extract (B10 or B11). Three weeks later they were injected intracardially with 0.25 to 1.0 ml. (0.14 to 0.53 mg. nitrogen) of the same extract with which they had been sensitized. All the animals reacted with anaphylactic shock. Nine died within 2 to 5 minutes, one in 10 minutes, and only one recovered (Table I).

Series II.—Six guinea pigs were injected with 3 to 5 ml. (1.25 to 2.05 mg. nitrogen) of banana extract (B11) (Table I).

A. Twenty-one days later, these were injected intracardially with 1.0 ml. (0.48 mg. nitrogen) of extract of dehydrated banana (DB2). None of the animals exhibited any evidence of sensitivity.

B. Two weeks later, these same animals were reinjected intracardially with 0.25 to 1.0 ml. (0.1 to 0.41 mg. nitrogen) of the same banana extract used for sensitization (B11). Four of the 6 guinea pigs died in acute anaphylactic shock.

Series III.—Five guinea pigs were given 3 to 5 ml. (1.44 to 2.40 mg. nitrogen) of extract of dehydrated banana (DB2) intraperitoneally (Table II).

A. Twenty-two days later, these were injected with 1.0 ml. (0.41 mg. nitrogen) of banana extract (B11) intracardially. None of the animals showed any evidence of sensitivity.

B. After another 16 days, these animals were reinjected intracardially with 1.0 ml. (0.41 mg. nitrogen) of extract of dehydrated banana (DB3). They showed no evidence of sensitivity.

Series IV.—Eleven guinea pigs were injected intraperitoneally with 1.0 to 3.0 ml. (0.35 to 1.44 mg. nitrogen) of extract of dehydrated banana (DB1 or DB2) (Table II).

A. After 21 to 24 days, 0.5 to 1.0 ml. (0.21 to 0.41 mg. nitrogen) of extract of dehydrated banana (DB1 or DB3) was given intracardially. No anaphylactic reactions were noted.

B. The same animals were reinjected intracardially with 0.4 to 1.0 ml. (0.16 to 0.53 mg. nitrogen) of banana extract (B10 or B11). None of the animals showed evidence of sensitivity.

Summarizing the results of these experiments, it is seen that:

Of the 17 guinea pigs sensitized with banana extract, 15 developed anaphylactic shock after receiving an intracardiac injection of the same extract. (Series I-A and Series II-B).

None of the 6 guinea pigs known to be sensitive to banana extract could be shocked by the injection of extract of dehydrated banana (Series II-A); nor could a potent banana extract shock 16 animals that were injected previously with extract of dehydrated banana (Series III-A and Series IV-B).

None of the 16 animals injected with the extract of dehydrated banana could be shocked with the homologous extract (Series III-B and Series IV-A).

OBSERVATIONS ON TWO PATIENTS SENSITIVE TO BANANA

In recent years, the following two cases of banana sensitivity came under the writers' observation.

CASE 1.—G. V., A 10-year-old boy, with ragweed hay fever and a positive family history for allergy, could eat banana without untoward reactions up to the age of 6 years. Since then, ingestion of as little as a teaspoonful of raw banana has been followed by protracted nausea, vomiting, and abdominal pain. On trial feeding, the child was able to eat commercial dehydrated banana with no ill effects.

CASE 2.—S. C., a 14-year-old girl, developed perennial allergic rhinitis at the age of 7, neurodermatitis 2 years later, and at the age of 12, bronchial asthma. Banana was known to cause severe abdominal cramps and diarrhea lasting two days. Contact of banana with the lips would cause local swelling and vesiculation. Other marked food sensitivities were present as well. Feeding of commercial dehydrated banana produced no ill effects.

Both patients gave marked (++++) intracutaneous reactions with banana extract diluted 1:10. However, extracts of dehydrated banana diluted 1:10 gave negative reactions.

Blood serum from patient G. V. was injected intracutaneously into two nonallergic substitutes for passive transfer studies." The substitutes were placed on a diet free from banana and other foods to which the patient had shown positive cutaneous reactions. The sites were tested intracutaneously with diluting fluid and with extracts of dehydrated banana and of raw banana. The results are given in Table III. The presence of specific skin-sensitizing antibodies for banana was demonstrated. However, these antibodies did not react with extracts of dehydrated banana.

TABLE I. GUINEA PIGS INJECTED INTRAPERITONEALLY WITH BANANA EXTRACT AND CHALLENGED INTRACARDIALLY WITH BANANA OR DEHYDRATED BANANA EXTRACT

SERIES	GUINEA PIG (NO.)	WEIGHT (GM.)	INTRAPERITONEAL INJECTION			A. FIRST INTRACARDIAL INJECTION					B. SECOND INTRACARDIAL INJECTION					TIME OF DEATH (MIN.)	
			ANTI-GEN	AMOUNT (ML.)	NITRO-GEN (MG.)	INTER-VAL (DAYS) *	ANTI-GEN	AMOUNT (ML.)	NITRO-GEN (MG.)	RE-SULT	TIME OF DEATH (MIN.)	INTER-VAL (DAYS)	ANTI-GEN	AMOUNT (ML.)	NITRO-GEN (MG.)		RE-SULT
I	1	275	B10	4.0	2.12	21	B10	1.0	0.53	X	3						
	2	355	B10	4.0	2.12	21	B10	0.5	0.27	X	3						
	3	240	B10	4.0	2.12	22	B10	0.25	0.14	X	4						
	4	390	B10	4.0	2.12	22	B10	0.25	0.14	X	5						
	5	360	B10	3.0	1.59	21	B10	0.25	0.14	X	3						
	6	430	B10	3.0	1.59	22	B10	0.25	0.14	X	10						
	7	290	B11	5.0	2.05	21	B11	1.0	0.41	X	2						
	8	245	B11	5.0	2.05	22	B11	1.0	0.41	X	5						
	9	220	B11	3.0	1.23	22	B11	1.0	0.41	X	3						
	10	230	B11	3.0	1.23	22	B11	1.0	0.41	X	4						
	11	215	B11	3.0	1.23	22	B11	0.4	0.16	+							
II	12	200	B11	3.0	1.23	21	DB2	1.0	0.48	0		35	B11	0.25	0.10	0	
	13	200	B11	3.0	1.23	21	DB2	1.0	0.48	0		35	B11	1.0	0.41	X	3
	14	210	B11	5.0	2.05	21	DB2	1.0	0.48	0		35	B11	0.5	0.2	X	4
	15	200	B11	3.0	1.23	21	DB2	1.0	0.48	0		35	B11	0.15	0.06	0	
	16	205	B11	5.0	2.05	21	DB2	1.0	0.48	0		35	B11	0.8	0.33	X	4
	17	210	B11	5.0	2.05	21	DB2	1.0	0.48	0		35	B11	0.25	0.10	X	3

*Number of days after intraperitoneal injection.

B10, B11 = Banana extracts.

DB2 = Dehydrated banana extract.

X = Died in anaphylactic shock.

+ = Positive but not fatal reaction.

TABLE II. GUINEA PIGS INJECTED INTRAPERITONEALLY WITH DEHYDRATED BANANA EXTRACT AND CHALLENGED INTRACARDIALLY WITH BANANA OR DEHYDRATED BANANA EXTRACT

SERIES	GUINEA PIG (NO.)	INTRAPERITONEAL INJECTION				A. FIRST INTRACARDIAL INJECTION				B. SECOND INTRACARDIAL INJECTION					
		WEIGHT (GM.)	ANTI-GEN	AMOUNT (ML.)	NITROGEN (MG.)	INTERVAL (DAYS) *	ANTIGEN	AMOUNT (ML.)	NITROGEN (MG.)	RESULT	INTERVAL (DAYS) *	ANTIGEN	AMOUNT (ML.)	NITROGEN (MG.)	RESULT
III	18	270	DB2	5.0	2.40	22	B11	1.0	0.41	0	38	DB3	1.0	0.41	0
	19	220	DB2	3.0	1.44	22	B11	1.0	0.41	0	38	DB3	1.0	0.41	0
	20	205	DB2	3.0	1.44	22	B11	1.0	0.41	0	38	DB3	1.0	0.41	0
	21	250	DB2	5.0	2.40	22	B11	1.0	0.41	0	38	DB3	1.0	0.41	0
	22	200	DB2	3.0	1.44	22	B11	1.0	0.41	0	38	DB3	1.0	0.41	0
IV	23	310	DB1	1.0	0.35	21	DB1	1.0	0.35	0	28	B10	1.0	0.53	0
	24	210	DB1	1.0	0.35	24	DB1	1.0	0.35	0	28	B10	1.0	0.53	0
	25	300	DB1	2.0	0.70	21	DB1	1.0	0.35	0	28	B10	1.0	0.53	0
	26	300	DB1	2.0	0.70	24	DB1	1.0	0.35	0	28	B10	1.0	0.53	0
	27	340	DB1	3.0	1.05	21	DB1	1.0	0.35	0	28	B10	1.0	0.53	0
	28	200	DB2	3.0	1.44	24	DB3	1.0	0.41	0	35	B11	1.0	0.41	0
	29	195	DB2	3.0	1.44	24	DB3	0.5	0.21	0	35	B11	0.4	0.16	0
	30	260	DB2	2.0	0.96	21	DB3	1.0	0.41	0	35	B11	1.0	0.41	0
	31	320	DB2	2.0	0.96	21	DB3	0.6	0.25	0	35	B11	1.0	0.41	0
	32	300	DB2	2.0	0.96	21	DB3	1.0	0.41	0	35	B11	1.0	0.41	0
	33	235	DB2	2.0	0.96	21	DB3	0.6	0.25	0	35	B11	1.0	0.41	0

*Number of days after intraperitoneal injection.

B10, B11 = Banana extracts.

DB1, DB2, DB3 = Dehydrated banana extracts.

TABLE III. PASSIVE TRANSFER STUDIES ON BLOOD SERUM OF PATIENT SENSITIVE TO BANANA (G. V.)

ANTIGEN Diluting fluid	REACTION	
	SENSITIZED SITE	CONTROL SITE
B10	++++	+
B10	+++	+
B11	+++	-
B11 1:10	++++	+
B11 1:100	++	±
DB1	-	-
DB1	-	-
DB2	±	±
DB2	±	±
DB2	±	±
DB3	+	+
DB3 1:10	-	-
Negative	-	Slight moderate ++
Slight negative	±	Moderate +++
Slight	+	Marked ++++
B10, B11 = Banana extracts.		
DB1, DB2, DB3 = Dehydrated banana extracts.		

DISCUSSION

Our experiments prove that banana extract has anaphylactogenic properties, producing shock in 15 of the 17 guinea pigs sensitized. We found that quantities of extract containing as little 1.23 mg. of nitrogen could sensitize a guinea pig, and as little as 0.14 mg. of nitrogen could shock one.

Raw, ripe banana contains 1.2 per cent protein, 23.0 per cent carbohydrate, 0.2 per cent fat, and 75.6 per cent water, in addition to minerals and vitamins.¹⁰ The extracts used in our experiments were analyzed for the total nitrogen content only. This was taken as the measure of the concentration of the extract and was presumed to approximate its antigenicity. The possible antigenic role of the other constituents, particularly carbohydrate, awaits further investigation.

The dehydrated banana used in our experiments contains 6.8 per cent proteins, 83.4 per cent carbohydrates, 1.3 per cent fat, minerals and vitamins, and only 5.5 per cent moisture.* The extract prepared from it contained approximately the same amount of total nitrogen per ml. as the banana extract. With the technique used, the extract of dehydrated banana was devoid of any sensitizing or shocking properties. Guinea pigs could not be sensitized with as much as 2.4 mg. of nitrogen of extract of commercial dehydrated banana (contained in 5.0 ml., which is the maximum that could be injected intraperitoneally at one time). As much as 0.41 mg. of nitrogen of the same extract failed to produce shock. This would seem to indicate that in the process of dehydration of the banana by heat, the antigen is so altered that its antigenic properties are destroyed.

It has been observed that food atopens such as milk and cereals could sensitize and shock guinea pigs. However, these same foods when processed by heat, as during cooking, canning, or dehydration, showed a marked reduction in their anaphylactogenic properties.¹¹⁻¹⁴

*Analysis as accepted by the Council on Foods and Nutrition of the American Medical Association.

The two cases presented showed immediate allergic gastrointestinal manifestations from ingestion of raw banana. That banana is a strong atopen was further demonstrated by direct intracutaneous testing and passive transfer studies. The reagins could not be demonstrated by using the extract of dehydrated banana. We assume, therefore, that this extract is devoid of active atopens. Moreover, the fact that the patients could tolerate considerable quantities of dehydrated banana attests further to its low allergenicity. One may assume that there is a definite place for this product in the hypoallergenic diet.

SUMMARY

1. Guinea pigs can be sensitized with an extract of raw banana, but not with a similarly prepared extract of the same nitrogen content of heat-processed, dehydrated banana flakes.

2. Guinea pigs specifically sensitized to the raw fruit can be shocked with the extract of raw banana, but not with the extract of the dehydrated banana.

3. Guinea pigs injected with dehydrated banana cannot be shocked with banana or dehydrated banana.

4. Two atopic children, clinically sensitive to banana, could ingest dehydrated banana without allergic manifestations. Although sensitive by cutaneous reactions to raw banana extract, both showed negative reactions to dehydrated banana. In one, the results of these cutaneous reactions were corroborated by passive transfer studies.

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