The Production of High-Protein Breads under Reduced Atmospheric Pressures[1]

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ABSTRACT

The production of high-protein breads under reduced atmospheric pressures eliminates the detrimental effects to bread quality of high levels of defatted soy flour, cottonseed flour, peanut flour, and fish protein concentrate without using chemical additives. Bread volumes increased with decreasing atmospheric processing conditions. The volume of breads supplemented with 15% of any of the forementioned protein additives and processed at 525 mm. Hg (10,000-ft. elevation) was as high as or higher than that of the control bread without protein additives processed at 765 mm. Hg (sea level). Bread grain, texture, crumb color, and flavor improved with decreasing atmospheric processing conditions. Due to the improvement in bread volume, the grain was less compact, the texture smoother, and the crumb color lighter. Baking at reduced atmospheric conditions caused partial loss of many objectionable flavor components of the supplements, resulting in a more pleasant aroma and flavor. High-protein additives were detectable and identifiable by a taste panel at the 15% level of supplementation in breads baked at 765 mm. Hg, but not when baked at 525 mm. Hg. This same trend was verified by gas-liquid chromatographic analysis. Bread fermentation and proofing times become increasingly shorter with decreasing atmospheric pressures.

For many years food scientists have been striving to improve the nutritional status of developing countries through fortifying grain products with essential nutrients (1,2,3) or by supplementing wheat and other indigenous cereal crops with high-protein, non-gluten-forming additives (1,4,5,6,7,8). Cottonseed flour (9,10), peanut flour (11), soy flour (12,13), fish protein concentrate (FPC) (14,15), and wheat protein concentrates (16), which are available in the U.S. and in many developing countries, have been used for this purpose.

A limiting factor to the use of cottonseed in human nutrition, the presence of the chemically reactive gossypol, has been overcome by eliminating gossypol through breeding (9) and through improved processing methods (10). Soy proteins have been shown to aid substantially in improving the quality of dietary protein sources (12), and can be used in bread-baking with little or no change in formulation (13). The possibilities of incorporating FPC into a variety of foods without affecting the desirable characteristics of the foods have been reported to be limitless (14,15). In addition to its excellent nutritive quality, FPC is considerably lower in cost than other animal-protein sources.

The possibility of protein supplementation has been investigated in products ranging from American white bread (4,13,14,17) to Indian chapatties (11,18) and Colombian corn cakes (19).

It is very difficult, however, to produce good quality baked goods with significant levels of any of the high-protein additives without detrimental effects on product quality. With the addition of 5% or more of these supplements bread-volume decreases, the grain becomes more open and the texture harsh, and

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bread flavor becomes increasingly objectionable (11). Improvements in bread volume can sometimes be achieved through use of a stronger flour (but this is not always available, especially in developing countries), or by use of emulsifiers and dough conditioners (5,20).

However, incorporation of chemical additives into foods has come under great attack in recent years. Many additives are now under investigation as potential health hazards and a number are likely to be eliminated from the list of additives permitted in U.S. foods. The food laws in many other countries also do not permit the use of certain chemical additives in baked foods. Production of high quality-high protein baked foods without the use of chemical additives is, therefore, desirable.

MATERIALS AND METHODS

This investigation was carried out in a special laboratory which consisted of a steel cylinder 7 ft. in diameter and 9 ft. high. This laboratory was fully equipped for the mixing, fermentation, proofing, and baking of breads, and could be ventilated and temperature and humidity controlled. The atmospheric pressure could be adjusted and maintained between 300 and 770 mm. Hg.

Baking Method

Pup loaves were baked at 765, 635, and 525 mm. Hg pressure by the straight-dough procedure and the following formulation: 6% sugar, 4% nonfat dry milk, 3% shortening, 2.5% yeast, 2% salt, 0.5% yeast food, and 0.3% calcium propionate. Both a baker's patent flour and a clear flour were used. Commercially available defatted soy flour, cottonseed flour, peanut flour, and FPC were added to the doughs, replacing 5, 10, and 15% of the wheat flour, respectively. The proximate analyses of the wheat flours and the high-protein additives as determined by AOAC methods (21) are given in Table I. The protein contents of the blends of wheat flour with the high-protein additives as well as baking absorptions determined with the mixograph are given in Table II. Fermentation times varied: 90 min. for processing at 765 mm. Hg; 80 min. at 635 mm. Hg; and 75 min. at 525 mm. Hg. The loaves were scaled 200 g. They were proofed to height and baked at 425° F. for 18 min.

Bread Evaluation

Specific volume was measured approximately 2 hr. after baking by rapeseed displacement, followed by an evaluation of external and internal bread

TABLE I. PROXIMATE ANALYSES OF WHEAT FLOURS AND HIGH-PROTEIN ADDITIVES

	Moisture %	Protein[a] %	Fat %	Ash %	Fiber %
Patent flour	9.9	12.4	0.7	0.4	0.2
Clear flour	11.3	13.4	1.3	0.7	0.4
Peanut flour	7.2	48.1	9.4	4.0	2.9
Cottonseed flour	9.5	54.7	2.4	6.7	3.3
FPC	2.2	78.1	0.4	19.1	0.0
Soy flour (defatted)	5.3	52.3	1.1	6.0	2.8

[a]N X 5.7 for wheat flours; N X 6.25 for protein additives.

TABLE II. PROTEIN CONTENTS, ABSORPTIONS, AND PROOFTIMES OF FLOUR BLENDS

Flour Composition	Protein %	Absorption %	Prooftimes (min.) at Atmospheric Pressures (mm. Hg) of		
			765	635	525
100% Patent flour	12.4	66	55	41	32
95% Patent + 5% cottonseed flour	14.5	66	54	39	31
90% Patent + 10% cottonseed flour	16.6	66	61	43	31
85% Patent + 15% cottonseed flour	18.8	66	60	43	37
95% Patent + 5% peanut flour	14.2	68	44	37	33
90% Patent + 10% peanut flour	16.0	71	50	40	33
85% Patent + 15% peanut flour	17.8	73	50	43	40
95% Patent + 5% defatted soy flour	14.4	70	69	48	36
90% Patent + 10% defatted soy flour	16.4	74	72	50	39
85% Patent + 15% defatted soy flour	18.4	78	72	50	39
95% Patent + 5% FPC	15.7	68	59	54	34
90% Patent + 10% FPC	19.0	70	62	59	35
85% Patent + 15% FPC	22.3	72	65	65	35

characteristics. The breads were scored for: crust color, 7; symmetry, 7; break and shred, 6; crumb color, 10; volume, 15; flavor, 15; grain, 20; and texture, 20 – the maximum number of points being indicated after each bread characteristic.

Flavor Evaluation by Gas-Liquid Chromatography

Besides a subjective evaluation of bread flavor, a simple gas-liquid chromatographic (GLC) technique was employed to detect flavor differences due to processing at various atmospheric pressures. Two hours after baking, loaves were cut in half and 2-ml. vapor samples were taken with a 2.5-ml. syringe directly out of the center of the cut loaves. The vapor samples were injected into a Hewlett-Packard Model 5750 gas chromatograph equipped with a dual column hydrogen-flame ionization detector. The 8-ft. columns were packed with 20% Carbowax 20 M on 60/80 mesh HMDS Chromosorb P. The injection port was 190°C.; column temperature, 85°C. isothermal; and the flame detector, 250°C. Tentative identification was accomplished by measuring relative retention times of known compounds reported to be present in bread (22) separated under the same gas-chromatographic conditions. The total peak area was calculated by multiplying the height of each peak by its width at one-half height and adding individual peak areas.

RESULTS AND DISCUSSION

Defatted Soy Flour

The effects of processing soybreads using a baker's patent flour under reduced atmospheric pressures are illustrated in Fig. 1. Bread which contained 5, 10, and 15% defatted soy flour was baked under 765, 635, and 525 mm. Hg pressure. At 765 mm. Hg pressure, bread volume decreased as the percentage of soy flour in the formula increased. The patent-flour control showed a specific volume of 4.00 cc. per g. This volume decreased to 3.41 cc. per g. at the 15% level of soy supplementation. Decreasing the atmospheric pressure to 635 and 525 mm. Hg increased the specific volume of the loaves at each level of supplementation, as

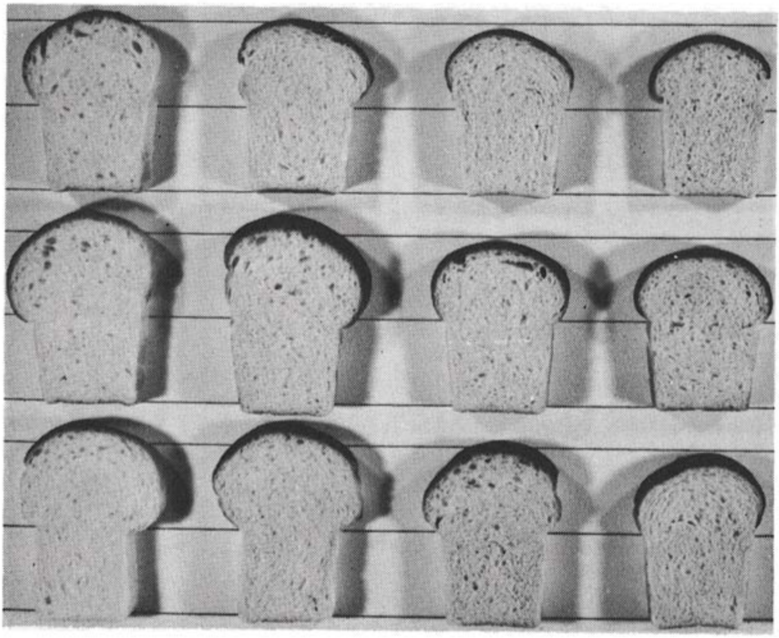

Fig. 1. The effects of processing under various atmospheric pressures on the quality of breads baked from blends of defatted soy flour and a baker's patent flour.

illustrated. With the improvement in bread volume, improvements both in grain and texture were noticeable. Since it was our aim to increase the protein content of the breads and retain as much as possible of other essential nutrients, portions of which are lost during milling, a clear flour was investigated which was higher in protein and ash but also higher in crude fiber. Breads baked from a clear flour supplemented up to 15% with a defatted soy flour are shown in Fig. 2. Bread specific volumes were considerably lower than those of breads baked with the patent flour, being 3.35 cc. per g. for the control and decreasing to 3.21 cc. per g. at 15% of soy supplementation at 765 mm. Hg pressure. However, bread volume increased and texture improved as the atmospheric pressure was lowered. Crumb color is affected by bread volume, and thus crumb colors became lighter as bread volume increased.

Dendy et al. (8) found flours with a high fiber and ash content less suitable for blends in bread-baking. The higher fiber and ash contents of the soy flour and the clear flour would explain the low specific bread volumes.

Cottonseed Flour

The specific volumes and total scores of breads baked from blends of patent flour and cottonseed flour are given in Table III. Bread specific volume decreased with increasing levels of supplementation at each atmospheric pressure, but increased significantly as the atmospheric pressure was lowered for processing from

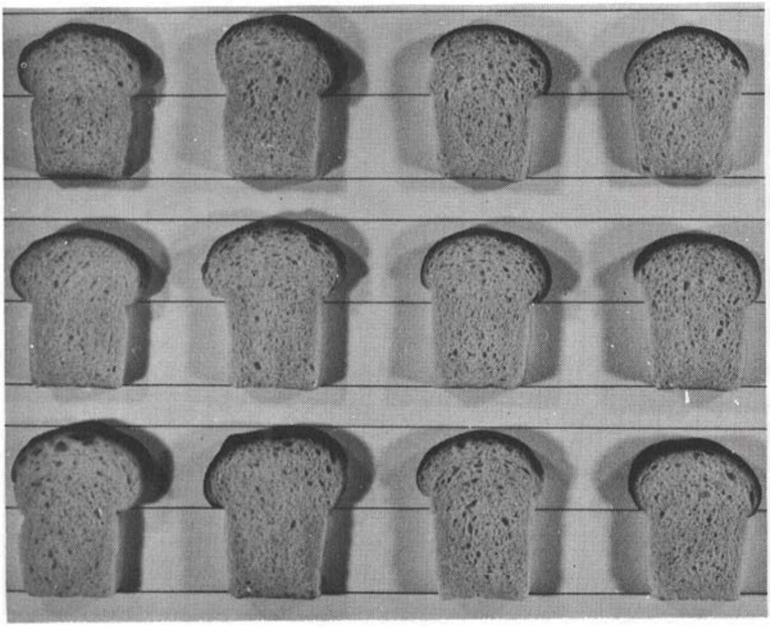

Fig. 2. The effects of processing under various atmospheric pressures on the quality of breads baked from blends of defatted soy flour and a clear flour.

TABLE III. SPECIFIC VOLUMES AND TOTAL SCORES OF BREADS BAKED FROM BLENDS OF PATENT FLOUR AND COTTONSEED FLOUR

Flour Blend	Specific Volumes (cc./g.)			Total Scores (maximum point=100)		
	Atmospheric pressure (mm. Hg)					
	765	635	525	765	635	525
100% Patent flour	3.29	3.93	4.56	73	85	88
95% Patent + 5% cottonseed flour	3.01	3.91	4.54	75	81	84
90% Patent + 10% cottonseed flour	2.98	3.47	4.58	71	77	82
85% Patent + 15% cottonseed flour	3.06	3.47	4.39	68	76	78

765 to 525 mm. Hg. At 765 mm. Hg the patent-flour control showed a specific volume of 3.29 cc. per g., increasing to 4.56 at 525 mm. Hg – a volume improvement of nearly 40%. At 765 mm. Hg the 15% level of cottonseed supplementation produced a bread specific volume of 3.06 cc. per g., increasing to 4.39 at 525 mm. Hg pressure – an increase of over 40%. It is interesting that the bread containing 15% cottonseed flour and processed at 525 mm. Hg of pressure was approximately 30% higher in volume than the patent-flour control without high-protein additive baked under 765 mm. Hg. With the improvements in bread volume, improvements in grain, texture, and crumb color were observed as the

atmospheric pressure was decreased. Higher bread scores were recorded at each level of supplementation as the atmospheric pressure was lowered for processing. Substituting the clear flour for the baker's patent flour in the wheat flour-cottonseed flour blends showed the same trends. Generally, however, bread specific volumes and total bread scores were slightly lower than those obtained for the blends with the baker's patent flour, as already reported for blends of clear flour and low-fat soy flour.

Peanut Flour

The effect of supplementation with peanut flour and processing under reduced atmospheric pressures is illustrated in Fig. 3. The specific volumes of the loaves baked with the baker's patent flour and the clear flour are given in Table IV. The

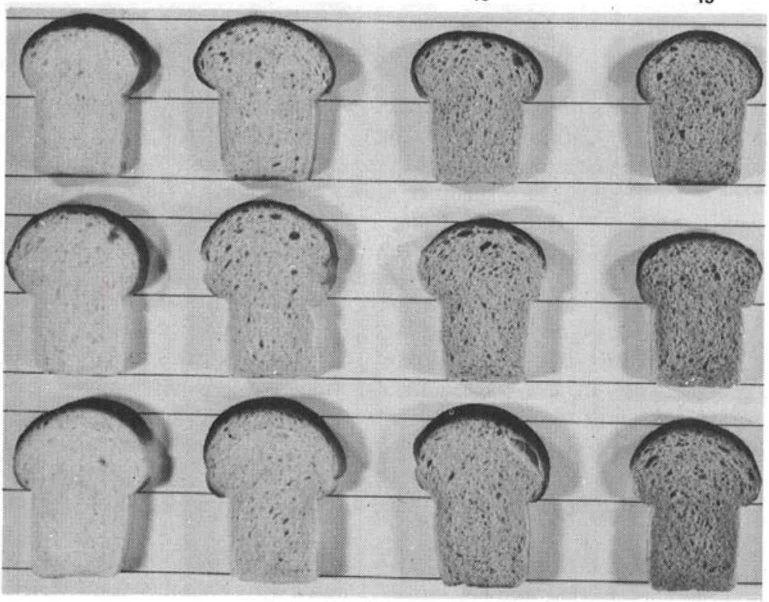

Fig. 3. The effects of processing under various atmospheric pressures on the quality of breads baked from blends of peanut flour and a baker's patent flour.

TABLE IV. SPECIFIC VOLUMES (cc./g.) OF BREAD BAKED FROM BLENDS OF WHEAT FLOURS AND PEANUT FLOUR

Atmospheric Pressure (mm. Hg)	Patent Flour and Peanut Flour Blends % peanut flour				Clear Flour and Peanut Flour Blends % peanut flour			
	0	5	10	15	0	5	10	15
765	3.97	4.11	3.81	3.53	3.64	3.55	3.53	3.39
635	4.25	4.43	3.77	3.58	3.87	3.84	3.62	3.49
525	4.44	4.76	4.32	4.04	3.99	4.06	3.67	3.25

patent flour again proved to be better suited for use in blends with high-protein additives than was the clear flour. The specific volume of the patent-flour control increased from 3.97 to 4.44 cc. per g., or about 10%, as the atmospheric pressure was reduced from 765 to 525 mm. Hg. The breads containing 15% peanut flour and baked at 525 mm. Hg pressure were again slightly higher in volume than was the patent flour control baked under an atmospheric pressure of 765 mm. Hg. Generally, the data indicate that bread specific volume decreased with increased supplementation at each atmospheric pressure used for processing, but also that volume increased with a reduction in atmospheric pressure from 765 to 525 mm. Hg at each level of supplementation.

Robinson (11), baking near sea-level atmospheric conditions, or approximately 765 mm. Hg, reported a bread specific volume of 2.83 cc. per g. and a total score of 32 with a low-protein flour (10.4% protein) and 15% peanut flour. With a medium-protein wheat flour (12.5% protein) and 15% peanut flour these values were 3.40 cc. per g. and 38, respectively. In our study, baking under 525 mm. Hg pressure resulted in a bread specific volume of 4.04 cc. per g. and a total score of 70, indicating the definite advantage of using reduced atmospheric pressures for the production of high-protein breads. With the improvements in bread volume, improvements in grain, texture, and crumb color were readily noticeable. The peanut flour, being the darkest of the high-protein additives used, caused considerable darkening of the crumb color at levels of supplementation above 5%. With processing at 635 and 525 mm. Hg pressure, crumb color of the loaves was considerably lighter as compared to those baked under 765 mm. Hg.

Fish Protein Concentrate

Breads baked with blends of patent flour and FPC under different atmospheric pressures are illustrated in Fig. 4. The advantage of baking under reduced pressures is again apparent. A level of supplementation of 15%, combined with baking under 525 mm. Hg pressure, produced a loaf of bread with a specific volume higher than that of the patent-flour control baked at 765 mm. Hg. The clear flour again proved to be less suitable. Improvements in grain, texture, and crumb color accompanied the increased bread volumes. The high ash content of the FPC (19.1%) caused a gritty crumb at levels of supplementation of 10% or above, which was considered to be objectionable.

Within the group of the high-protein additives – defatted soy flour, cottonseed flour, peanut flour, and FPC – the soy flour blended with either patent or clear flour caused the greatest reduction in bread volume with increasing levels of supplementation, while cottonseed flour caused the least. Bread volumes, however, increased considerably as the atmospheric pressure was lowered for processing with each of the additives, blended with either the baker's patent flour or the clear flour.

Flavor Evaluation

FPC contributes a characteristic flavor and taste to the bread which is more objectionable than the defatted soy flour, cottonseed flour, and peanut flour used in this investigation. However, it was observed that baking at reduced atmospheric conditions caused a partial loss of many objectionable flavor components of supplements, resulting in a more pleasant aroma and flavor. The high-protein additive was easily detectable and identifiable by a taste panel in bread at 10 and 15% levels of supplementation when the bread was baked under 765 mm. Hg of

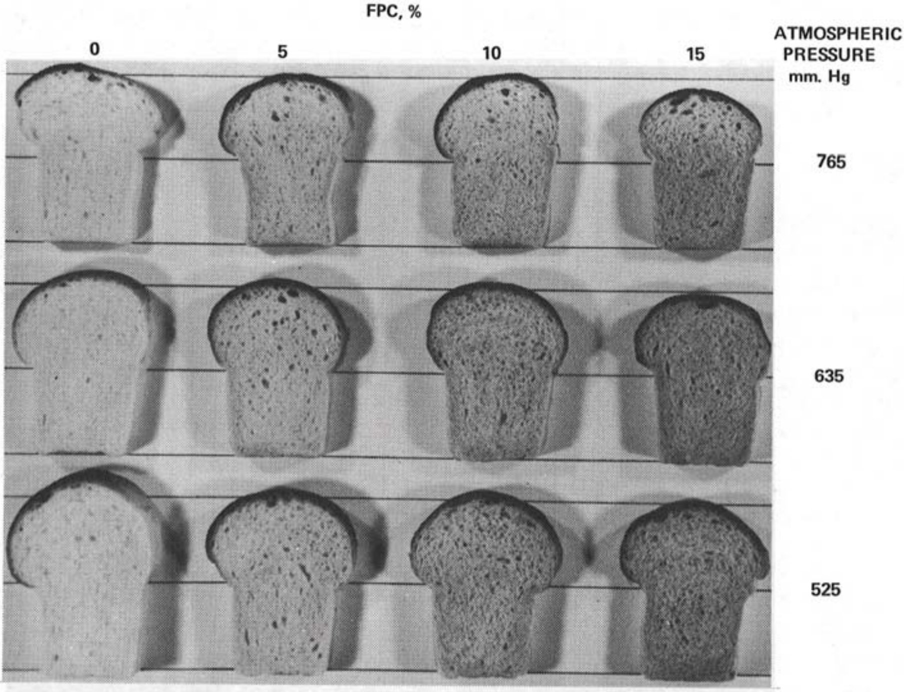

Fig. 4. The effects of processing under various atmospheric pressures on the quality of breads baked from blends of FPC and a baker's patent flour.

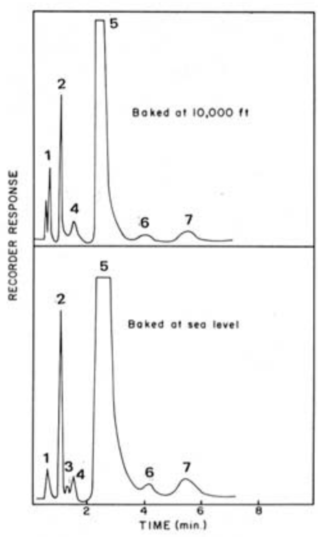

Fig. 5. GLC aroma-profile of breads containing 15% FPC and baked at 765 mm. Hg (sea level) and 525 mm. Hg (10,000-ft. elevation), respectively. Peak identification: 1 = acetaldehyde; 2 = acetone; 3 = unknown; 4 = 2-butanone; 5 = ethanol; 6 = 2-hexanone; 7 = butanol.

pressure, but not when baked at 525 mm. Hg. A GLC aroma-profile of bread containing 15% FPC and baked at 525 and 765 mm. Hg, respectively, is shown in Fig. 5. Tentatively identified were acetaldehyde, acetone, 2-butanone, ethanol, 2-hexanone, and butanol. Total peak area decreased from 6.0 $cm.^2$ for the bread baked at 765 mm. Hg pressure to 3.8 $cm.^2$ for that baked at 525 mm. Hg, indicating a greater loss of volative compounds with baking under reduced pressures. It is not implied that the smaller amounts of acetone and ethanol, especially, in the bread baked under 525 mm. Hg are solely responsible for the milder flavor of breads supplenented at the 10 or 15% levels. No GLC column, even if operated over a wide temperature range, can assure complete separation and detection of all compounds as related to odor or flavor. Most of the objectionable odor associated with FPC is of an amine nature, and is not efficiently separated with the column used. However, Fig. 5 illustrates that there is indeed a loss of volatile components in high-protein supplemented breads if the atmospheric pressure is lowered for processing, resulting in flavor improvement. Breads supplemented with defatted soy flour, cottonseed flour, and peanut flour also showed a smaller peak area of the aroma profile when the atmospheric pressure during processing was reduced from 765 to 525 mm. Hg.

Prooftimes

Prooftimes increased as the level of supplementation was increased under a given set of processing conditions. However, prooftimes decreased as the atmospheric pressure was lowered for processing. This is shown in Table II. This general decrease in the time required for doughs to reach a given height for the same proportion of yeast as the atmospheric pressure decreased might be attributed to the greater volume of the carbon dioxide or to the greater ease of gas expansion at reduced atmospheric pressures.

Total processing time of breads made by the straight-dough procedure normally is 4 to 5 hr. Because of shorter fermentation and prooftimes when baking under reduced pressures, this total time can be reduced by 10 to 20%, permitting a larger production in a given time.

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