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PUFFED ORGANIC MATERIAL AND METHOD OF MAKING SAME

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This invention relates to the puffing of organic materials.

The present application is a continuation-in-part of my copending application, Serial No. 296,963, filed July 2, 1952, now abandoned, which in turn is a continuation-in-part of my applications, Serial No. 40,630, filed July 24, 1948, now abandoned, and copending Serial No. 189,679, filed October 11, 1950, now abandoned. My application, Serial No. 189,679, filed October 11, 1950, was a continuation-in-part of my following applications: Serial No. 34,821, now abandoned; Serial No. 34,822, now abandoned; and Serial No. 34,823, now abandoned, all filed June 23, 1948; Serial No. 23,869, filed April 28, 1948, now abandoned; Serial No. 38,179, filed July 10, 1948, now abandoned; and Serial No. 40,630, filed July 24, 1948, now abandoned.

Reference is had to the related cases of John M. Baer and Frank B. Doyle, Serial No. 62,984, filed December 1, 1948; Allison and Carman, Serial No. 161,744, filed May 12, 1950, now abandoned; Carman and Allison, Serial No. 259,313, filed November 30, 1951, now abandoned; and Carman and Allison, Serial No. 275,458, filed March 7, 1952, now abandoned.

The problem of puffing organic materials and particularly organic cellular materials, involves a large number of interlocking variables. In the first place, the material, itself, must be sufficiently elastic that it can be puffed. It must have cells or other divisions within it which will trap expanding gas and thus provide the pressure differential necessary for puffing. A sudden drop in pressure must be provided of such amount to produce the pressure difference necessary not only to expand the cell walls but to do so in spite of the leakage that necessarily occurs. On the other hand, the pressure difference must be great enough to exceed the elastic limit of the material before puffing has occurred. The expansability of the cell wall normally depends upon the moisture content of the product, the condition of that moisture as to being free or combined, the temperature of the article and its chemical condition, particularly as to whether it is cooked or uncooked.

Likewise, there must not only be the pressure difference required to institute puffing, but there must be a volumetric increase of the gases involved sufficient to maintain it.

I have now found that another factor involved, which has hitherto been completely overlooked but the accomplishment of which is inherent in the operation described in my previous applica-

tions referred to, is that once the article has been puffed, the puffed condition must be maintained even after the pressure difference has been removed. One of the difficulties encountered in many instances of puffing in the prior art was that an article could be puffed, but after puffing would collapse because of the weakened condition of the walls following the leakage out of the gas which produced puffing. This was particularly true if, after puffing, the pressure outside of the puffed article was increased.

I have now found that by suddenly cooling and dehydrating the product so that its final temperature is below 150° F. and preferably well below 100° F.—as for example, from 32° F. or lower up to, say, 100° F., that the cell walls of the product on puffing are cold set so that on standing or on the application of pressure, even of a greatly increased amount, collapse does not occur.

These results are obtained automatically by following the procedures already outlined in my previous applications. In these procedures, the following points are important:

1. Substantially all of the air should be removed from the product and replaced by an atmosphere of steam prior to puffing.

2. The product should be cooked by steam or otherwise or moistened preferably by the addition of substantially air-free steam at higher pressure and temperature until the condition of the material is proper for puffing and its moisture content is within the desired range. The use of the process permits the introduction of substantially more moisture than was permissible under the old processes.

3. It is preferred that the sudden release of pressure be into a maintained vacuum zone which is initially below eight inches of mercury absolute. The conditions of the resulting explosion should be such as to cause cold setting of the puffed product. This means that in actual practice, employing commercially practicable vacuum equipment, the pressure may ride up somewhat during the puffing step. It is preferred to continue evacuation of the vacuum zone during the puffing step so as to cause cold setting of the puffed product. The expansion of air-free steam into a vacuum of four inches of mercury absolute will automatically reduce the temperature of the product to approximately 125° F. Reduction of the pressure to two inches reduces the temperature approximately to 100° F. Reduction to one inch reduces it to about 79° F. and reduction to 0.2 inch reduces it to approximately 34° F.

Furthermore, by puffing into a maintained vacuum zone, it is possible to obtain a greater temperature drop in number of degrees between the maximum and minimum than was ordinarily obtainable heretofore. The result of this greater temperature drop was to permit the evaporation of more water from the product by boiling. This boiling not only maintained the pressure difference for puffing, but the removal of the water helped to cold set the cell walls by reducing plasticity and elasticity. The combination of the moisture reduction plus chilling, particularly below 100° F., has produced results not heretofore obtainable.

In a vacuum process, this reduction of temperature is of particular significance, since the lower the vacuum used the greater is the increase in pressure after the completion of the puffing operation when the material is taken back into the atmosphere. If it were not for the cooling and drying effects, many products would not be able to maintain their puffed condition when the pressure is increased, for example from two inches absolute to thirty inches absolute—an increase of fifteenfold.

The removal of the air from inside the organic material in the first instance has a number of advantages. In the first place, the oxygen of the air has a deleterious effect on many products, particularly when they are heated. Secondly, the removal of non-condensable gases increases the permeability of the material to heat and to steam so that heating will occur uniformly and the steam will penetrate equally to all portions of the material.

Thus, when it comes to introducing steam for increasing the moisture content of the product and for cooking it to the necessary chemical and physical conditions, the fact that air is not present inside the organic material produces a rapidity and uniformity of steaming and cooking not otherwise possible. Because of this greater uniformity and speed, it is possible to go to higher temperatures and pressures than would otherwise be possible. Normally, however, it permits the use of lower temperatures and pressures than otherwise required. As an example of this, raw wheat having a weight of 188 grams per unit of volume (one cup) approximately, was subjected to a series of tests. Various samples of the wheat were cooked for fifteen minutes at thirty-five pounds gauge of steam pressure, in each case after removing substantially all of the air from the grains.

In the first group of tests, pressure was then increased to 100 pounds with steam held for fifteen seconds and the product then puffed to the full chamber vacuum of approximately 0.2 inch of mercury absolute. The weight of the material per cup dropped from an average of 188.5 grams (average of five samples) to 18.7 grams (average of five samples).

The following table shows the weights before and after puffing of five samples of wheat.

Table I

Raw Wheat	Grams	#875	Grams
1	188	1	19
2	188	2	19
3	188.5	3	18.5
4	189	4	18
5	189	5	19

On the other hand, in the second group of tests after the cooking, the steam was replaced by 100 pounds of air pressure which was held for fifteen seconds and then the material puffed to the same full chamber vacuum. In this, the five original samples had the same average weight as before but the average weight per cup after puffing, instead of being 18.7 grams was 150 grams for the five samples.

On the other hand, wheat cooked in the same manner for the same time and then having the pressure raised to 115 pounds with steam air-free, held for fifteen seconds and then puffed to atmosphere showed an average final weight per cup of 60.1 grams for five samples as compared to the 18.7 when puffed to the vacuum. 115 pounds was used here in order to have the same pressure differences as in the first one in which the 100 pound pressure was puffed to full vacuum.

The actual pressure to be employed before puffing will vary depending on the particular product concerned. With many products, temperature is a very important factor and since with saturated steam, free from air, the temperature of the product is directly dependent upon the pressure, it frequently is desirable to use the minimum temperature and pressure possible. Thus, some products may be puffed without exceeding atmospheric pressure at the time of the puff, and in some cases the puffing pressure may be puffed without exceeding atmospheric pressure at the time of the puff, and in some cases the puffing pressure may be actually sub-atmospheric.

On the other hand, for inorganic materials like vermiculite, the upper temperature is usually unimportant.

Tobacco is an example of a material which is extremely heat sensitive, although some kinds of tobacco are less so, and the stem portions are generally less so than the leaf portions of the stem.

The Doyle patent, No. 2,627,221, which issued February 3, 1953, shows a puffing apparatus particularly suitable for carrying out the processes herein described. In such an apparatus a steaming chamber is provided within which the product may be placed. This steaming chamber is connected by a triggered door to an expansion chamber. The expansion chamber is preferably kept at a very low pressure, means being provided to maintain a low pressure during the puffing. The steaming chamber is provided with evacuating means, steaming means, and usually with a purge line through which non-condensible gases can be eliminated as well as some condensed steam which is developed during steaming.

As an example of the process, durum wheat was introduced to the steaming chamber. Air and other non-condensible gases were removed from the wheat grains by reducing the pressure in the steaming chamber to about 0.2 inch of mercury absolute while withdrawing the generated steam. Saturated steam was then introduced and the pressure increased to 35 pounds gauge, and held at this point for fifteen minutes to substantially completely cook the material without loss of cellular identity. The steam pressure was then raised to 100 pounds per square inch gauge, held for 15 seconds, following which the wheat was fired into the expansion chamber which in this instance was at a pressure of 0.2 inch of mercury absolute. This firing is done by suddenly releasing the triggered door of the expansion chamber and the resulting explosion ejects the wheat into the expansion chamber. The potentiometer indicated a temperature at the moment of the puff at slightly below 32° F. indicating an actual super-cooling of the material.

The actual values of the variables in the cooking-puffing cycles of this method depend upon the condition and type of material being used, as well as the degree of puffing desired.

The extent of the puffing secured may be varied in a number of ways. The moisture content of the product is one factor. Its temperature is another. Its physical condition as a result of cooking is another. The pressure employed is another. Products which have been puffed to the same extent are by no means necessarily alike in their physical, chemical, and taste properties. Particularly important is the ability to rehydrate, which may be very much different for two particles of inherently the same size. This does not mean that a predetermined product may not be produced. Using the same base material and treating it in the same way will produce on all occasions a substantially identical product.

As a further example of the process, tobacco stems which had been redried in a conventional manner and then stored until they were dry to the touch and were brittle, were first moistened, preferably in the puffing apparatus, until they were slightly pliable. At the conclusion of the moistening operation, the particular stems were in an atmosphere of steam under a pressure of approximately two inches of mercury absolute. They were then subjected to an increasing steam pressure until the temperature had risen 180° to 250° F., corresponding to about eight pounds to thirty pounds absolute. The material was then puffed by opening of the triggered door into the explosion or expansion chamber at a pressure of approximately 0.2 inch of mercury absolute, which pressure was maintained during the operation, as in the previous cases, by operation of the evacuation system in the expansion chamber during the puffing. Because of this operation, the pressure was not permitted to rise above approximately one inch of mercury absolute during puffing. Similar operations have been carried out upon leaf tobacco suitably moistened before the operation. In the case of leaf tobacco, the pressure difference and other conditions should not be such as to shatter the leaves unduly.

In another operation, green tobacco, that is tobacco which had not been redried, was placed in loose hands in the steaming chamber. Air was then removed by production of a vacuum to a point at which water would boil from the tobacco. The pressure at this point was 0.2 inch of mercury absolute which was held for four minutes after which steam was introduced to raise the pressure to 20 pounds gauge and this was held for two minutes. The trigger was then pulled and the material puffed into the expansion chamber which was at 0.2 inch of mercury absolute and which was maintained at a low pressure by continued evacuation.

Preferred moisture content for the tobacco is upwards of 13% and normally from 14% to 18% before puffing and, in fact, before the steaming operation. With redried tobacco, higher pressures such as 45 to 60 pounds gauge may be employed.

In the case of starchy products such as wheat, the cooking and moisture condition of the material have a more profound effect than in products like tobacco.

In the case of rice, the rice grains in their dried state may be employed without moistening. However, in some instances it may be desired to supply flavor, and/or moistening, and/or nutritional values to the grain prior to, during, or after puffing. This may be done by the use of a liquid carrier, such as water, under high temperature and pressure which is exploded into the vessel maintaining the product under high vacuum in an atmosphere of steam. By using water under a pressure and temperature corresponding to that, of say, 100 pounds gauge of steam, the particles may be exploded into a fine mist which will penetrate the grains, particularly after they have been puffed. In this way moisture, sugar, salt, certain vitamins, and nutritional salts may be supplied to the material with or without other flavoring agents. This may be done immediately following the initial evacuation (i. e., during cooking) or immediately following the puffing. It is less economical to do it at some intermediate stage.

The rice should be thoroughly cooked for desirable puffing. I have found that cooking at 20 pounds steam pressure gauge for about five to seven minutes produces satisfactory results. Following cooking in the steaming chamber, the steam pressure was increased rapidly; for example, in thirty seconds to a pressure of 90 pounds gauge or higher, as for example, 100 pounds gauge, after which the pressure was immediately (and instantaneously) reduced to subatmospheric, preferably below eight inches of mercury absolute and particularly to about 0.2 inch of mercury absolute. This was done by opening the triggered door of the puffing apparatus and firing the rice into the expansion chamber. The pressure within the expansion chamber was maintained at a low point by continuing the evacuation during the puffing and normally the pressure in that chamber was not permitted to exceed four inches of mercury absolute and preferably not permitted to exceed two inches of mercury absolute. In some instances, however, I have operated successfully with the pressure in the expansion chamber following explosion riding up to as high as 4 to 8 inches of mercury absolute as measured on a standard mercury manometer, but in most instances the pressure was reduced below 4 inches of mercury absolute within a few minutes and before reimposition of atmospheric pressure.

The actual values of the variables in the cooking-puffing cycles of this method depend upon the condition and type of rice being used, as well as the degree of puffing desired.

The resulting vacuum puffed rice has a volume of from about 6 to 12 times the original kernels as determined by their cup weights. Put conversely, the specific gravity, as determined from cup weights, is from 8⅓% to 16⅔% of the specific gravity of the original kernels. The shape of the original kernels is maintained, although greatly enlarged. On cross-section, some of the vacuum puffed rice kernels will be found to have a small central hollow spot, but this is relatively small compared to previously puffed rice. The average cell size appears to be from one fifth to one tenth the diameter of the usual puffed material. The cell walls are glassy or vitreous in appearance, and give a snow white appearance to the inside of the grain, although apparently the walls are transparent. Under magnification the interior of the grain resembles a snow field. The exterior of the puffed rice grain is not case hardened, and upon wetting, water is immediately and instantly absorbed throughout. After soaking in water at 65° F. for about 10 minutes, the vacuum puffed rice grains retain their entity and shape and do not break up even when mashed down on a microscopic slide, whereas a corresponding commercially puffed rice soaked under the same conditions is collapsed and when mashed down on a microscopic slide the tissue breaks down completely. When iodine is added to the vacuum puffed rice grains soaked in water at 65° F. for10 minutes, there is substantially little or no change in its color, indicating that under this condition, the starch is substantially water insoluble. Iodine added to commercially puffed rice grains under the same conditions immediately changes color on contacting the water, indicating that the starch of such rice is water soluble under similar conditions.

By "commercially puffed rice" I mean a commercially available puffed rice produced by the stand rd prior art processes such as Warren Patent No. 2,261,456.

Examples of applying the method of this invention to rice are:

Example 1

Short-grained Arkansas Riceland "500" rice (15 pounds) was placed in the steam chamber, subjected to a pressure of 1.5 inches of mercury absolute for 2 minutes, the rice being at a temperature of about 91° F., to remove substantially all of the non-condensable gases from the rice grains. The rice was then steamed quickly to a steam pressure of 20 pounds per square inch gauge, held at this pressure for 7 minutes accompanied by continual purging of the steam, steamed to 100 pounds per square inch gauge, held at this pressure for 15 seconds, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grains were cold set.

Example 2

15 pounds of rice were treated in the same manner as in Example 1, except that the step of subjecting the rice to 1.5 inches of mercury absolute for 2 minutes prior to steaming was omitted.

Example 3

Arkansas Riceland rice (15 pounds) was placed in the steam chamber and the pressure reduced to 1.5 inches of mercury absolute for 2 minutes, the rice being at a temperature of about 91° F., to remove substantially all of the non-condensable gases. The rice was then steamed to a pressure of 20 pounds per square inch gauge in 5 minutes, held there for 2 minutes, steamed to 100 pounds per square inch gauge in 5 minutes, held there for 2 minutes, following which the pressure was decreased to 80 pounds gauge, held there for 15 seconds, and the rice then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grains were cold set.

The puffed rice grains from Examples 1 and 2 were very satisfactory having the above described characteristics. However, when a sample of rice was treated in the same manner as described in Example 1 except that the steps of subjecting it to 1.5 inches of mercury absolute prior to steaming and of purging during steam-

ing were both omitted, i. e., the non-condensable gases were not removed prior to vacuum puffing, the resulting puffed rice grains were a total loss, as over 90% of them were reduced to fines similar to brewers' grits. This indicates the importance of removing the non-condensable gases from the rice grains prior to puffing.

A sample of the vacuum puffed rice of Example 3 above showed 50% nitrogen efficiency as compared to a negative efficiency by a commercially puffed rice.

In the case of wheat, the wheat grains in their normal dry state may be employed without moistening. However, in some instances it may be desired to supply flavor, and/or moistening, and/or nutritional values to the grain, prior to, during, or after puffing. This may be done in the same manner as previously described in the case of rice.

The wheat should be thoroughly cooked for desirable puffing. I have found that cooking at from about 35 to 100 pounds steam pressure gauge for a period of from about 1½ to 15 minutes produces satisfactory results. Following cooking in the steaming chamber, the steam pressure was adjusted to form about 35 to 100 pounds gauge, after which the pressure was then immediately (and instantaneously) reduced to subatmospheric, preferably below 8 inches of mercury absolute and particularly to about 0.2 inch of mercury absolute. This was done by opening the triggered door of the puffing and firing the wheat into the expansion chamber. The pressure within the expansion chamber was maintained at a low point by continuing the evacuation during the puffing and normally the pressure in that chamber was not permitted to exceed 4 inches of mercury absolute and preferably not permitted to exceed 2 inches of mercury absolute. In some instances, however, I have operated successfully with the pressure in the expansion chamber following explosion riding up to as high as 4 to 8 inches of mercury absolute as measured on a standard mercury manometer, but in most instances the pressure was reduced below 4 inches of mercury absolute within a few minutes and before reimposition of atmospheric pressure.

The actual values of the variables in the cooking-puffing cycles of this method depend upon the condtion and the type of wheat being used as well as the degree of puffing desired.

The resulting vacuum puffed wheat has a volume of from about 4 to 10 times the original grains, as determined by their cup weights. Put conversely, the specific gravity as determined by cup weights is from about 10% to 25% of the specific gravity of the original wheat grains. The vacuum puffed wheat particles are everted, substantially pure white except for the bran particles adhering thereto, and are entirely different in shape from the original wheat grains. The cellular structure is vitreous in appearance. On cross-section, the puffed grains have a large number of relatively large carvities substantially uniformly distributed throughout the interior. These cavities while by no means spherical are generally rounded at their protuberances.

The vacuum puffed wheat grains are immediately wettable by water, except in those portions protected by the bran fragments and when immersed in water at 65° F., for a period of 10 minutes, they retain their entity and shape and do not break down even when mashed on a microscopic slide.

Examples of applying the method of this invention to wheat are:

Example 4

Red durum wheat was placed in a steam chamber which was then evacuated to an absolute pressure of about 0.2 inch of mercury absolute, the temperature of the wheat being not less than about 40° F., to remove substantially all of the non-condensable gases. The wheat was then steamed to a pressure of 35 pounds per square inch gauge, held there for 8 minutes accompanied by continual purging of the steam, quickly steamed to 100 pounds gauge, held there for about 15 seconds, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grains were cold set.

Example 5

Red durum wheat (15 pounds) were placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the wheat being at a temperature of not less than 40° F., to remove substantially all of the non-condensable gases from the wheat grains. The wheat was then steamed to a pressure of 100 pounds per square inch gauge, held there for 2 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grains were cold set.

Example 6

Red durum wheat (5 pounds) was placed in the steam chamber and the pressure reduced to 0.2 inch of mercury absolute for 2 minutes, the wheat being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The wheat was then steamed to 75 pounds per square inch gauge in ½ minute, held there for 1½ minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grains were cold set.

Example 7

Wheat (5 pounds) was placed in the steam chamber and the pressure reduced to 0.2 inch of mercury absolute for 2 minutes, the wheat being at a temperature not less than 40° F., to remove substantially all of the non-condensable gases. The wheat was then steamed to a pressure of 75 pounds per square inch gauge, held there for 4 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grains were cold set.

Example 8

Red durum wheat (20 pounds) was placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the wheat being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The wheat was then steamed to a pressure of 100 pounds per square inch gauge, held there for 5 minutes, following which the steam pressure was quickly reduced to

50 pounds per square inch gauge, and then the wheat was fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grains were cold set.

Example 9

Wheat was treated in the same manner as in Example 4 except that in the step of removing the non-condensable gases from the wheat grains prior to steaming, the period of evacuation at 0.2 inch of mercury absolute pressure was 1 minute instead of 2 minutes.

Example 10

Wheat was treated in the same manner as in Example 4 except that in the step of removing the non-condensable gases from the wheat grains prior to steaming, the period of evacuation at 0.2 inch of mercury absolute pressure was 5 minutes instead of 2 minutes.

Example 11

Wheat (20 pounds) was placed in the steam chamber and the pressure reduced to 0.2 inch of mercury absolute for 2 minutes, the wheat being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The wheat was then steamed at a pressure of 100 pounds per square inch gauge in 95 seconds, held there for 5 minutes and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grains were cold set.

The puffed wheat grains from Examples 4 to 11 were very satisfactory, having the above described characteristics. Samples of the vacuum puffed wheat from these examples showed from 11% to 15% thiamine retention and 78% to 87% lysine retention. A standard commercial puffed wheat showed 0 thiamine retention and 35% lysine retention. The sample from Example 9 had the 11% thiamine retention determination and that from Example 10 had the 15% thiamine retention determination.

The lysine retention was likewise greater for the vacuum puffed wheat product which had been evacuated for 5 minutes before steaming, i. e., Example 10.

The puffed wheat product produced by the process of this method showed 51% nitrogen efficiency by a feed test compared to a negative efficiency for a corresponding commercially puffed wheat.

In the case of farina or wheat middlings, farina in its normal dry state may be employed without moistening. However, in some instances it may be desired to supply flavor, and/or moistening and/or nutritional value to the grain, prior to, during, or after puffing. This may be done in the same manner as previously described in the case of rice.

The farina should be thoroughly cooked for desirable puffing. I have found that cooking at from 40 to 100 pounds steam pressure gauge for a period of about 2 minutes produces satisfactory results. Following cooking, the steam pressure was adjusted to from 40 to 100 pounds gauge, after which the pressure was then immediately reduced to sub-atmospheric, preferably below 8 inches of mercury absolute and particularly to about 0.2 inch of mercury absolute. This was done by opening the triggered door of the puffing apparatus and firing the farina into the expansion chamber. The pressure within the expansion chamber was maintained at a low point by continuing the evacuation during the puffing and normally the pressure in that chamber was not permitted to exceed four inches of mercury absolute and preferably not permitted to exceed 2 inches of mercury absolute. In some instances, however, I have operated successfully with the pressure in the expansion chamber following explosion riding up to as high as 4 to 8 inches of mercury absolute as measured on a standard mercury manometer, but in most instances the pressure was reduced below 4 inches of mercury absolute within a few minutes and before reimposition of atmospheric pressure.

The actual values of the variables in the cooking-puffing cycles of this method depend upon the condition and the type of wheat middlings being used as well as the degree of puffing desired.

The resulting vacuum puffed farina has a volume of from about 4 to 8 times the original farina particles as determined by cup weights. Put conversely, the specific gravity as determined by cup weights is from about 12½% to 33⅓% of the specific gravity of the original farina particles. The shape of the original particles is roughly maintained although the outer surface of the puffed material is rough. The product is not case hardened so far as can be observed. The vacuum puffed farina is not transparent but is translucent, having a milky-white appearance.

Examples of applying the method of this invention to farina are:

Example 12

Farina (5 pounds) was placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the farina being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The farina was then quickly steamed to a pressure of 75 pounds per square inch gauge, held there for 2 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the farina particles were cold set.

Example 13

Farina (5 pounds) was placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the farina being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The farina was then quickly steamed to a pressure of 60 pounds per square inch gauge, held there for 2 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the farina particles were cold set.

Example 14

Farina (5 pounds) was placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the farina being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The farina was then quickly steamed to a pressure of 40 pounds per square inch gauge, held there for 2 minutes accompanied by continual purging of the steam, quickly steamed to 75 pounds per square inch gauge, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the farina particles were cold set.

Example 15

Farina (5 pounds) was placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the farina being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The farina was then quickly steamed to a pressure of 100 pounds per square inch gauge, held there for 2 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the farina particles were cold set.

Example 16

Farina (20 pounds) was placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the farina being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The farina was then steamed to a pressure of 50 pounds per square inch gauge, held there for 2 minutes, quickly steamed to 70 pounds gauge, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued absolute during the puff until the farina particles were cold set.

Example 17

Farina (20 pounds) was placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the farina being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The farina was then quickly steamed to a pressure of 40 pounds per square inch gauge in 30 seconds, held there for 2 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the farina particles were cold set.

When the vacuum puffed farina prepared in the manner described above is mixed with cold or hot milk, it is ready for consumption within ½ minute or less. Thus, this vacuum puffed farina is a ready-to-eat cereal.

A number of runs were made to determine the rate of hydration of the vacuum puffed farina of this invention. For each run, the hydration determinations were made using 180 gram samples. One sample of each run was placed in a container having one quart (946 grams) of water maintained at about 70° F. After 1, 5, 10, and 20 minute intervals, the water-farina mixture was poured into a strainer while substantially all of the free water passed into a measuring cup in from 10 to 20 seconds. After weighing the free water, it and the farina were again placed in the container. The difference in weight between the free water in the container just prior to placing the farina sample therein and the weight of free water at each time interval was the amount of water absorbed by the farina at that particular time.

It was found that the amount of water absorbed by the vacuum puffed farina was more than 400% of the original dry weight of the farina after 5 minutes. When compared with the hydration of commercial farinas, the farina product of this invention absorbs approximately 3½ times as much water at the end of 5 minutes than a commercial farina under the same conditions.

In the case of oats, the oat grains in their normal dry state may be employed without moistening. However, in some instances it may be desired to supply flavor, and/or moistening, and/or nutritional values to the grain, prior to, during, or after puffing. This may be done in the same manner as previously described in the case of rice.

The oats should be thoroughly cooked for desirable puffing. I have found that cooking at from 50 to 100 pounds steam pressure gauge for a period of from about 4 to 18 minutes produces satisfactory results. Following cooking, the steam pressure was adjusted to from 75 to 100 pounds gauge, after which the pressure was then immediately reduced to sub-atmospheric, preferably below 8 inches of mercury absolute and particularly to about 0.2 inch of mercury absolute. This was done by opening the triggered door of the puffing apparatus and firing the oats into the expansion chamber. The pressure within the expansion chamber was maintained at a low point by continuing the evacuation during the puffing and normally the pressure in that chamber was not permitted to exceed four inches of mercury absolute and preferably not permitted to exceed 2 inches of mercury absolute. In some instances, however, I have operated successfully with the pressure in the expansion chamber following explosion riding up to as high as 4 to 8 inches of mercury absolute as measured on a standard mercury manometer, but in most instances the pressure was reduced below 4 inches of mercury absolute within a few minutes and before reimposition of atmospheric pressure.

The actual values of the variables in the cooking-puffing cycles of this method depend on the condition and type of oats being used as well as the degree of puffing desired.

The resulting vacuum puffed oats have a volume of from about 4 to 8 times the original grains as determined by their cup weights. Put conversely, the specific gravity as determined by cup weights is about 12½% to 25% of the specific gravity of the original oat grains. The vacuum puffed oat grains are everted, substantially pure white except for the bran particles adhering thereto, and are entirely different in shape from the original oat grains. The cellular structure is vitreous in appearance and the product is immediately wettable by water except for those portions protected by the bran fragments which adhere to the puffed oat particle.

The vacuum puffed oats, puffed according to the method of this invention, may be stored for long periods of time under atmospheric conditions without becoming rancid. Samples have been stored in containers for periods of from 3 to 6 months under atmospheric conditions without turning rancid.

Examples of applying the method of this invention to oats are:

Example 18

Hulled oats (10 pounds) were placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the oats being at a temperature not less than about 40° F., to remove substantially all of the non-condensable gases. The oats were then steamed to a pressure of 100 pounds per square inch gauge, held there for 6 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the oat grains were cold set.

Example 19

Hulled oats (10 pounds) where treated in the same manner as in Example 18, except that in the steaming and puffing cycles, the oats were steamed to 50 pounds per square inch gauge, held there for 15 minutes, steamed quickly to 100 pounds per square inch gauge, held there for 2 minutes, and then fired into the expansion chamber.

Example 20

Hulled oats (10 pounds) were treated in the same manner as in Example 18, except that in the steaming and puffing cycles, the oats were steamed to 60 pounds per square inch gauge, held there for 15 minutes, quickly steamed to 100 pounds per square inch gauge, held there for 3 minutes, and then fired into the expansion chamber.

Example 21

Hulled oats (10 pounds) were treated in the same manner as in Example 18, except that in the steaming cycle the oats were steamed to a pressure of 100 pounds per square inch gauge and held there for 8 minutes instead of 6 minutes.

Example 22

Hulled oats (35 pounds) were treated in the same manner as in Example 18, except that in the steaming cycle the oats were steamed to a pressure of 100 pounds per square inch gauge and held there for 4 minutes instead of 6 minutes.

Example 23

Hulled oats (10 pounds) were treated in the same manner as in Example 18, except that in the steaming cycle the oats were steamed to a pressure of 100 pounds per square inch and held there for 10 minutes instead of 6 minutes.

Example 24

Hulled oats (10 pounds) were treated in the same manner as in Example 18, except that in the steaming and puffing cycles the oats were steamed to a pressure of 100 pounds per square inch gauge, held there for 6 minutes accompanied by continual purging of the steam, following which the steam pressure was reduced to 75 pounds per square inch gauge, held there for 15 seconds, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute.

Example 25

Hulled oats (10 pounds) were treated in the same manner as in Example 18, except that in the steaming and puffing cycles the oats were steamed to a pressure of 100 pounds per square inch gauge, held there for 6 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute.

Example 26

Hulled oats (20 pounds) were treated in the same manner as Example 18, except that in the steaming and puffing cycles the oats were steamed to a pressure of 100 pounds per square inch gauge in 2 minutes, held there for 5 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute.

Example 27

Hulled oats (10 pounds) were treated in the same manner as Example 18, except that in the steaming and puffing cycles the oats were steamed to a pressure of 55 pounds per square inch gauge in 15 minutes, quickly steamed to 100 pounds gauge, held there for 1 minute, and then fired into the expansion chamber which was at a pressure of about 0.2 inch of mercury absolute.

Example 28

Hulled oats (10 pounds) were treated in the same manner as Example 27, except that in the steaming and puffing cycles the oats were subjected to a pressure of 100 pounds per square inch gauge for 6 minutes instead of 1 minute, and then fired into the expansion chamber which was at a pressure of about 0.2 inch of mercury absolute.

Puffed oats are not commercially available and therefore no comparisons can be made. However, a puffed oat prepared by the present process by freeing from air, steaming at 55 pounds gauge for 15 minutes, raising to 100 pounds gauge, holding there for 1 minute, and then puffing to a substantial vacuum showed 62% lysine retention.

Another vacuum puffed oat product similarly prepared except that it was held at 100 pounds gauge for 6 minutes showed 65% lysine retention.

In the case of corn and particularly corn grits, or hominy, corn grits in their normal dry state may be employed without moistening. However, in some instances it may be desired to supply flavor, and/or moistening, and/or nutritional values to the grain, prior to, during, or after puffing. This may be done in the same manner as previously described in the case of rice.

The corn grits should be thoroughly cooked for desirable puffing. I have found that cooking at from 70 to 100 pounds steam pressure gauge for a period of from about 1 to 11 minutes produces satisfactory results. Following cooking, the steam pressure was adjusted to form 60 to 100 pounds gauge, after which the pressure was immediately reduced to sub-atmospheric pressure, preferably below 8 inches of mercury absolute and particularly to about 0.2 inch of mercury absolute. This was done by opening the triggered door of the puffing apparatus and firing the corn grit into the expansion chamber. The pressure within the expansion chamber was maintained at a low point by continuing the evacuation during the puffing and normally the pressure in that chamber was not permitted to exceed four inches of mercury absolute and preferably not permitted to exceed 2 inches of mercury absolute. In some instances, however, I have operated successfully with the pressure in the expansion chamber following explosion riding up to as high as 4 to 8 inches of mercury absolute as measured on a standard mercury manometer, but in most instances the pressure was reduced below 4 inches of mercury absolute within a few minutes and before reimposition of atmospheric pressure.

The actual values of the variables in the cooking-puffing cycles of this method depend on the condition and type of corn grits being used as well as the degree of puffing desired.

The resulting vacuum puffed corn grit has a volume of from about 6 to 10 times the original grit as determined by cup weights. Put conversely, the specific gravity as determined from cup weight is from about 10% to 16⅔% of the specific gravity of the original corn grit particles. The shape of the original corn grit is maintained, although greatly enlarged. On cross-section, the vacuum puffed corn grit has a substantially pure white interior and the interior cells are apparently uniformly expanded, there being but a few small cavities present. The outer surface surrounding the interior portion is comprised of a thin layer having many minute cavities substantially uniformly distributed therethrough. This outer surface is not case hardened and is substantially free of any surface splitting.

Examples of applying the method of this invention to corn, and particularly corn grits, are:

Example 29

No. 4/5 corn grits (20 pounds) were placed in the steam chamber and the pressure reduced to about 0.2 inch of mercury absolute for 2 minutes, the grits being at a temperature of not less than 40° F., to remove substantially all of the noncondensable gases. The grits were next steamed to a pressure of 100 pounds per square inch gauge in 5 minutes accompanied by continual purging of the steam, and then fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grits were cold set.

Example 30

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles the grits were steamed to 100 pounds for 3½ minutes, and then fired into the expansion chamber.

Example 31

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles, they were steamed to 90 pounds per square inch gauge in 2½ minutes and then fired into the expansion chamber.

Example 32

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles, they were steamed to 95 pounds per square inch gauge in 2 minutes 15 seconds, held there for 1 minute, the steam pressure quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 33

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles, they were steamed to 95 pounds per square inch gauge in 127 seconds, held there for 1 minute, the steam pressure reduced quickly to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 34

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles, they were steamed quickly to 95 pounds per square inch gauge, held there for 1 minute, the steam pressure was quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 35

No. 4/5 corn grits (5 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles, they were rapidly steamed to 95 pounds per square inch gauge, held there for 1 minute, the steam pressure was quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 36

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were steamed to 75 pounds per square inch gauge in 4 minutes, held there for 1 minute, the steam pressure was quickly reduced to 70 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 37

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were steamed to 80 pounds per square inch gauge in 4 minutes, held there for 2 minutes, and then the grits were fired into the expansion chamber.

Example 38

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were steamed to 80 pounds per square inch gauge in 4 minutes, held there for 4 minutes, the steam pressure was quickly increased to 100 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 39

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were rapidly steamer to 75 pounds per square inch gauge, held there for 8 minutes, and then the grits were fired into the expansion chamber.

Example 40

No. 4/5 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were steamed to 70 pounds per square inch gauge in 4 minutes, held there for 7 minutes, and then the grits were fired into the expansion chamber.

Example 41

No. 8/10 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were steamed to 95 pounds per square inch gauge in 1 minute 55 seconds, held there for 1 minute, the steam pressure was quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 42

No. 8/10 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were steamed to 95 pounds per square inch gauge in 140 seconds, held there for 1 minute, the steam pressure was quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 43

No. 8/10 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were rapidly steamed to 95 pounds per square inch gauge, held there for 1 minute, the steam pressure was quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 44

No 8/10 corn grits (5 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were rapidly steamed to 95 pounds per square inch gauge, held there for 1 minute, the steam pressure quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 45

No. 8/10 corn grits (20 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were steamed to 75 pounds per square inch gauge in 4 minutes, held there for 1 minute, the steam pressure was quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 46

No. 8/10 corn grits (17 pounds) were treated in the same manner as in Example 29, except that in the cooking and puffing cycles they were steamed to 75 pounds per square inch gauge in 4 minutes, held there for 2 minutes, the steam pressure was quickly reduced to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber.

Example 47

No. 4/5 corn grits (20 pounds) were placed in the steam chamber and steamed to a pressure of 75 pounds per square inch gauge in 4 minutes accompanied by continual purging of the steam, held there for 2 minutes, the pressure was rapidly decreased to 60 pounds per square inch gauge, and then the grits were fired into the expansion chamber which was at a pressure of 0.2 inch of mercury absolute. Evacuation of the expansion chamber was continued during the puff until the grits were cold set.

The vacuum puffed corn grits from Examples 29 to 47 were very satisfactory having the above described characteristics.

The present process instantaneously cools the product to a low temperature because of the expansion into a low absolute pressure. This prevents deterioration which would otherwise be caused by the puffing temperature as well as helping to cold set or gel the walls so that they will not collapse upon reimposition of atmospheric conditions.

The products are preferably dried under the puffing vacuum without re-exposure to air. Normally a final moisture content of about 7–9% is suitable for wheat. It is generally desirable to be below the normal equilibrium moisture content of the material in all cases. This usually means a drop of about 3% in the drying operation. Drying is preferably accomplished by radiant heat under the vacuum.

The products may be dried by other means—as by oven drying. Oven drying produces case hardening and some toasting. For some purposes a slight case hardening and toasting are suitable and may be desirable. The case hardening markedly slows down absorption of aqueous liquids.

As an instance of the applicability of the process to the preparation of a pre-cooked cereal having the ability of cooking promptly, reference is made to the application of Carman and Allison, Serial No. 299,496, filed July 17, 1952. That case primarily relates to a pre-cooked rice having a weight per quart of about 28.5% to 60% of the original material.

The particular conditions of the presently claimed process adapted for the production of pre-cooked rice and other cereals are the invention of Carman and Allison described in the other copending applications referred to. That process and those products are, however, likewise within the generic concept of the present invention.

The present process not only produces puffed materials which cannot be duplicated by any other process of which I know, but it has a wide range of adaptability to produce various characteristics. The process may be used to produce materials which are not case hardened. On the other hand by appropriate treatment, the products may be prepared so that they are case hardened, the operator having a selectivity which was not characteristic of any other process.

Likewise, the present puffing process is the only one which produces a product free from scorched appearance or taste. On the other hand, if desired, the products may be pre-toasted or after-toasted or crisped to provide whatever taste is desired and may be obtained by proper heat treatment.

Likewise, as the present process retains the nutritive value of the materials beyond that obtainable by known processes.

In the treatment of tobacco, green hands of bright tobacco were severed so that one portion consisted of the butts cut off about five inches from the end and the remaining portion consisted of the leaves above that point. The leaf portions were placed in the pressure or steam chamber and the pressure in this chamber reduced to a high vacuum of about 0.1 inch of mercury absolute. Steam was then admitted to bring the pressure to about 3 to 5 pounds gauge. The steaming was at such a rate that the total time of steaming above zero gauge was about two minutes and not more than one minute at five pounds. The conditions just given are for bright tobacco. Burley will stand a more severe handling without affecting the leaves. During the steaming operation, a bleed line communicating with the steam chamber was left open to avoid condensation. The pressure was suddently reduced by opening of the triggered door of the explosion or expansion chamber, which chamber was maintained at a pressure of about 0.2 inch of mercury absolute. The pressure in this chamber was not permitted to rise above approximately 2 inches of mercury absolute.

The butts were placed in the pressure chamber, subjected to the high vacuum and then steamed. For bright tobacco, the steaming operation was carried on at from six to eight pounds gauge, the time over zero pounds gauge and the time at maximum pressure being not more than one minute. The bleed line communicating with the steam chamber was left open during steaming. The butts were then exploded under substantially the same conditions as the leaves, but were kept separated therefrom.

The foregoing detailed description is given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

I claim:

1. The method of puffing cereals which comprises freeing a cereal from air and replacing the air with an atmosphere of steam, cooking the cereal for a period sufficient to soften the cell walls and adapt them for puffing, then subjecting the cereal to a sudden change from a high super-atmospheric pressure to a low sub-atmospheric pressure whereby it is puffed.

2. The method as set forth in claim 1 in which the cereal is cooked under a pressure of steam of approximately 10 to 40 pounds per square inch gauge.

3. The method as set forth in claim 1 in which the cereal is cooked under a pressure of steam of approximately 10 to 30 pounds, and the pressure thereon is then rapidly increased to a pressure in excess of 90 pounds per square inch, following which the product is immediately puffed.

4. The method as set forth in claim 1 in which the product is rice, and is cooked for a period of 5 to 7 minutes at a pressure of 20 pounds per square inch gauge.

5. The method as set forth in claim 1 in which the product is rice, and is cooked for a period of 5 to 7 minutes at a pressure of 20 pounds per square inch gauge, and the pressure is then increased to approximately 100 pounds per square inch gauge within less than 1 minute.

6. The method which comprises cooking a cereal in an atmosphere of steam, suddenly reducing the pressure below 8 inches of mercury absolute to puff the cereal, and then drying the puffed cereal under the sub-atmospheric pressure.

7. The method as set forth in claim 6 in which the drying is accomplished while supplying heat to the material.

8. The method which comprises puffing a food product by a sudden reduction in pressure in an atmosphere of steam and concluding the operation at an absolute pressure substantially below 8 inches of mercury absolute, and then introducing a volatile liquid at a temperature sufficiently high to have an internal vapor pressure markedly above atmospheric, said mist containing additive flavoring or nutritive ingredients whereby the liquid explodes into a fine mist and penetrates the food product.

9. In the puffing of cellular materials, the steps of heating the material in the presence of moisture to produce a super-atmospheric steam pressure thereon and then puffing the product into a maintained vacuum sufficiently low to cold set the product by evaporation of moisture from and consequent cooling of the product and reimposing atmospheric pressure upon the product while in cold set condition.

10. The process of claim 9 in which the puffing operation is carried out as a batch process, the puffing being into a vacuum which is initially at substantially absolute zero pressure and which rises during the puffing operation to a point not above an average pressure of 4 inches of mercury absolute.

11. The process of claim 9 in which the puffing operation is carried out as a batch process, the

puffing being into a vacuum which is initially at substantially absolute zero pressure and which rises during the puffing operation to a point not above an average pressure of 2 inches of mercury absolute.

12. The method of claim 9 in which the product is dried after the puffing operation is complete but before reimposition of atmospheric pressure.

13. The method of claim 9 in which the temperature of the product is reduced below 100° F. before reimposition of atmospheric pressure.

14. The method of claim 9 in which the temperature of the product is reduced below 50° F. before reimposition of atmospheric pressure.

15. The method of claim 9 in which the temperature of the product is reduced below 150° F. before reimposition of atmospheric pressure.

16. A cold set, vacuum puffed cereal produced by the process of claim 9.

17. A cold set, vacuum puffed rice product produced by the process of claim 9.

18. A cold set, vacuum puffed cellular material produced by the process of claim 9.

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