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(72) Inventeurs/Inventors:
AXELROD, GLEN S., US;
GAJRIA, AJAY, US

(73) Propriétaire/Owner:
T.F.H. PUBLICATIONS, INC., US

(74) Agent: GOWLING LAFLEUR HENDERSON LLP

(54) Titre : METHODE POUR MOULER DE L'AMIDON COMESTIBLE

(54) Title: METHOD OF MOLDING EDIBLE STARCH

(57) **Abrégé/Abstract:**

A process for forming starch into a molded article using melt processing techniques which process comprises combining starch and water to form a mixture wherein the water content is in the range of about 20.0 to 40.0 % by weight with respect to that of the starch and introducing and heating the mixture in an extruder wherein the water content of said product upon discharge from said extruder is less than the water content of the mixture entering said extruder. The extrudate is then, optionally dried, and introduced to a heated injection molding machine and injection molding and cooled to form a molded article wherein the water content of the molded article is at or below about 20 % by weight.



1 **Abstract**

2

3 A process for forming starch into a molded article using melt processing
4 techniques which process comprises combining starch and water to form a mixture
5 wherein the water content is in the range of about 20.0 to 40.0 % by weight with respect
6 to that of the starch and introducing and heating the mixture in an extruder wherein the
7 water content of said product upon discharge from said extruder is less than the water
8 content of the mixture entering said extruder. The extrudate is then, optionally dried, and
9 introduced to a heated injection molding machine and injection molding and cooled to
10 form a molded article wherein the water content of the molded article is at or below about
11 20 % by weight.

12

METHOD OF MOLDING EDIBLE STARCH

This invention relates to a method of manufacturing edible starch products with specific utility in the form of an edible product for an animal or as a chew toy for a pet. The manufacturing method disclosed herein employs melt mixing of starch with selected amounts of additives, including water and other fillers, followed by injection molding into a selected shape. The processing conditions, including barrel temperatures and cooling profiles, as in the case of extrusion compounding, are also uniquely adjusted along with additive amount and water levels to provide molded starch products with greatly improved performance characteristics.

The prior art is replete with disclosures directed at converting starch or related materials into a molded or shaped article. The following discussion therefore provides a brief chronological overview of the development of such technology as it has appeared in the patent literature over the past several decades.

For example, starting with U.S. Patent No. 2,602,755 (1952) entitled "Thermoplastic Compositions of Water-Soluble Cellulose Ethers" it was disclosed that powdered methyl cellulose of a water soluble variety could be blended with a particular narrow range of mixtures of propylene glycol and glycerin to provide compositions which could be molded or extruded when pressure was applied at temperatures of 150⁰ to 170⁰ C, without decomposition. This was then followed by U.S. Patent No. 3,137,592 (1961) entitled "Gelatinized Starch Products" which described a method of preparing homogenous gelatinized starch products, which method was characterized by intense mechanical working or shearing of the starch at elevated temperatures and pressures in the presence of a minor-proportion of a starch-swelling agent. The method goes on to disclose the use of a screw-type extruder, along with water as the preferred starch-swelling agent or plasticizer due to its low cost and relatively low boiling point.

Attention is next directed to U.S. Patent No. 3,038,895 (1962) entitled "Water-Dispersible Partially Substituted Derivatives of Amylose" which describes a means for producing an amylose derivative which was readily dispersed in water without the need to exceed temperatures above 130⁰ C, which dispersion was identified as "viscosity stable",

1 thereby forming films of excellent water resistance. Shortly thereafter, in U.S. Patent No.
2 3,074,803 (1963) entitled "Molding Starch Composition" a method was disclosed for
3 preparing molded starch compositions, which method focused on the blending of high
4 melting point fatty acid esters with starch which blends are then said to provide a
5 composition relatively free of oil build-up along with what was said to be a minimum of
6 starch dusting.

7 This was followed by U.S. Patent No. 3,117,014 (1964) entitled "Amlaceous
8 Compositions for Shaped Articles and Process" which described starch compositions
9 which are said to flow under heat and pressure which compositions comprise a derivative
10 of amylaceous material, a plasticizer for said derivative, and water, wherein the amount of
11 water is between 1.0 - 20 % by weight. Turning next to U.S. Patent No. 4,076,846 (1978)
12 entitled "Protein-Starch Binary Molding Composition and Shaped Articles Obtained
13 Therefor" an edible, water-soluble thermoplastic molding composition comprising a
14 starch material is disclosed, along with a neutral inorganic alkali salt of protein material,
15 water, an edible plasticizer, an edible lubricant, and other additives. Such compositions
16 were said to have excellent moldability and processibility when subjected to various
17 common plastics processing techniques, such as compression molding, transfer molding,
18 extrusion molding, blow molding, inflation molding, injection molding, vacuum forming,
19 pressuring forming, heat sealing, etc.

20 More recent disclosures include U.S. Patent No. 4,673,438 (1987) entitled
21 "Polymer Compositions and Injection Molding". This disclosure states that capsules and
22 other shaped products can be formed from a starch composition comprising starch, with a
23 molecular mass range of 10,000 to 20,000,000 Daltons, along with a water content from
24 5-30 % by weight. The recited process using an injection molding machine requires that
25 one maintain a starch/water composition at a water content of 5-30% by weight of the
26 composition under controlled conditions of temperature and pressure, heating said
27 starch/water composition at elevated pressure above its glass transition temperature and
28 melting point while maintaining said water content to form a melt, further heating and
29 plasticizing said molten starch/water composition to dissolve the starch in the water to

1 form what is stated to be an essentially molecularly dispersed solution of the melt. This is
2 followed by injecting the starch/water melt into a mold cavity while maintaining a
3 predetermined water content, and cooling the composition in the mold to form a molded
4 product at a temperature below the glass transition temperature of the composition and
5 ejecting the molded product from the mold.

6 In U.S. Patent No. 4,738,724 (1988) entitled "Method for Forming Pharmaceutical
7 Capsules from Starch Compositions" injection molded capsules of starch are disclosed,
8 for pharmaceutical applications, which method, similar to the '438 Patent discussed
9 above, recites that one first provide a starch water mixture having a water content in the
10 range of about 5 to 30 % by weight based on the weight of starch and water. This is
11 followed by heating the starch/water composition at elevated temperatures above its glass
12 transition temperature and melting point while maintaining the water content to form a
13 melt, followed by further heating and plasticizing said molten starch-water composition
14 to dissolve the starch in the water followed by injection molding of the plasticized starch
15 at elevated temperature and pressure into a mold, and forming a multi-chambered
16 configuration, and ejecting the molded capsule from the mold.

17 U.S. Patent No. 5,405,564 (1995) entitled "Method of Forming Shaped Articles
18 Made From Pre-Processed Starch" recites a process of forming shaped articles from
19 starch. The method is described as having surprisingly established that in the process of
20 injection molding starch, there are two important steps that are preferably separated. That
21 is, this disclosure recites that one must first heat a starch/water mixture wherein the water
22 content is about 10 % to about 20 % by weight with respect to that of said starch, in a
23 closed volume to a temperature within the range of about 120°C to about 190°C at a
24 pressure corresponding to the vapor pressure of water at the used temperature and up to
25 about $150 \times 10^5 \text{ N/m}^2$, to form a melt, wherein said melt is extruded and cooled to a
26 solidified and granulated product. This is then followed by heating such solid starch
27 composition, wherein the water content of said solid composition is about 10 % to about
28 20 % by weight with respect to that of said starch, in the screw barrel of an injection
29 molding machine or an extruder, at a temperature of from about 80°C to about 200°C,

1 and at a pressure of from about zero to about 150×10^5 N/m² for a time long enough to
2 form what is termed as a melt of destructureized starch, transferring said melt of
3 destructureized starch to a mold or extruding said melt of destructureized starch while
4 maintaining the water content in the range of from about 10 % to about 20 % by weight
5 with respect to that of the composition, and cooling said melt of destructureized starch in
6 said mold or outside said extruder to form a solid shaped article.

7 Finally, attention is directed to the following United States Patents and copending
8 applications, commonly owned by the assignee herein: U.S. Patent Nos. 5,200,212;
9 5,240,720; 5,476,069; U.S. Patent Application Serial Nos.: 08/923,070 filed September 3,
10 1997 entitled "Vegetable Based Dog Chew"; 08/738,423 filed October 25, 1997 entitled
11 "Edible Dog Chew"; 08/784,834 filed January 17, 1997 entitled "Carrot-Based Dog
12 Chew"; 08/888,611 filed July 7, 1997 entitled "Vegetable Dog Chew"; 09/114,872 filed
13 July 14, 1998 entitled "Heat Modifiable Edible Dog Chew"; 08/993,748 filed December
14 19, 1997 entitled "High Starch Content Dog Chew"; 09/138,804 filed August 21, 1998
15 entitled "Improved Edible Dog Chew"; 09/116,070 filed July 15, 1998 entitled "Wheat &
16 Casein Dog Chew With Modifiable Texture"; 09/116,555 filed July 15, 1998 entitled
17 "Heat Modifiable Peanut Dog Chew". In addition to such patents and applications,
18 attention is also directed to the art cited in said patents and applications, as such art
19 relates to the field of molded starch products.

20 As is apparent from the above review of the prior art, a variety of efforts have
21 been developed to convert starch, with minimum degradation, into a molded product of a
22 desired configuration. Such efforts have focused on the use of propylene glycol, fatty
23 acid esters, alkali salts of protein material and/or water as a starch additive, followed by
24 melt processing techniques such as extrusion and/or injection molding. With respect to
25 the use of water, although it has been disclosed that water apparently assists in regulating
26 starch degradation, there has been an intensive and on-going search for some key or
27 optimum water level, which when combined with a corresponding optimum processing
28 profile, fully prevents the starch from overheating and ultimately degrading, and therefore
29 leading to the development of molded products of highest possible quality.

1 Accordingly, the present invention has as its primary object to formulate a starch
2 composition, followed by a processing/molding profile, which formulation and
3 processing/molding profile affords a molded starch product with mechanical property
4 performance that vastly improves over those starch products reported in the art.

5 In addition, it is also a primary object of this invention to develop and optimize
6 the additive level for a starch composition such that the starch, subsequent to a desired
7 melt processing technique and conversion into a desired shape, will have optimum and
8 unique properties suitable for the manufacture of an edible starch product and/or chew toy
9 for a pet.

10 A process for forming starch into a molded product using melt processing
11 techniques, and the product produced by said process, which process comprises
12 combining starch and water to form a mixture wherein the water content is in the range of
13 about 20.0 to 40.0 % by weight with respect to that of said starch, introducing and heating
14 said mixture in an extruder wherein the water content of said product upon discharge
15 from said extruder is less than the water content of said product entering said extruder,
16 and introducing the product of (b) to a heated injection molding machine and injection
17 molding and cooling to form said molded article wherein the water content of said
18 molded article is at or below about 20 % by weight.

19 In accordance with the present invention, a method of manufacturing edible starch
20 products is disclosed, which employs extrusion melt mixing of starch with selected
21 amounts of additives, including water and other fillers, followed by injection molding
22 into a selected shape. Preferably, the products herein have been manufactured in the form
23 of chew toys and other similarly shaped products for pets.

24 Tables 1-6 herein illustrate the various processing parameters and product
25 characteristics of the various preferred embodiments for manufacturing the shaped
26 products of the present invention. As can be seen in the accompanying tables, preferably,
27 potato starch, or for that matter, any carbohydrate of natural or vegetable origin,
28 composed mainly of amylose and/or amylopectin, can be used in accordance with the
29 present invention. It may be extracted from various plants, such as potatoes, rice, tapioca,

1 corn and cereals such as rye, oats and wheat. Particularly preferred, however, is potato
2 starch and corn starch, flour and mixtures thereof.

3 The water content of the starch is first set in the range of about 20 - 40 % by
4 weight with respect to that of the starch, which mixture is preferably achieved by mixing
5 the starch with water in a Wenger DDC Preconditioner that provides controlled pre-
6 moisturization and complete mixing of the water with the starch material. This is then
7 followed by placement of the starch/water combination into an extruder, and in that
8 regard, preferably, a Wenger TX Magnum Extruder is employed, available from the
9 Wenger Company. While twin-screw operation is preferred, single screw extrusion is
10 also an acceptable alternative. The conditions for extrusion, including such variables as
11 extruder shaft speed, control temperatures of the various extruder zones, heat pressure,
12 etc., are all listed in the accompanying tables. Finally, in the context of the present
13 invention, where the water level charged in the extruder is preferably lowered during the
14 course of extrusion, a vented barrel extruder is employed, wherein such venting lowers
15 the water level to a desired level. To facilitate such water level change, it has been found
16 particularly useful to apply a light vacuum to the extruder barrel at the vent port, to
17 thereby provide a more efficient removal of water from the extrudate therein.

18 As already noted, water levels for the starch/water mixture charged into the
19 extruder begin at about 20-40 % by weight, but preferably, water content is best adjusted
20 to the following ranges of water content: 25-35 %, 30-35 %, and 30-33 %. In particularly
21 preferred embodiment, the water level of the starch/water mixture entering the extruder is
22 at about 31.2 %, 31.1 %, 30.2 %, 22.5 %, and 25.2 % as shown in Examples I-V in the
23 accompanying Tables 1-6. However, in accordance with the present invention, those
24 skilled in the art will recognize that the ranges are only preferred, and other levels of
25 water may be optionally selected within the broad teachings provided herein. The
26 resulting products of extrusion are conveniently formed in the shape of beads, the size of
27 which can be made to vary in accordance with standard pelletizing equipment.

28 Once extruded bead is produced, and as can be seen from the various preferred
29 embodiment identified in the accompanying Tables, the water level of the bead exiting

TABLE 1
EXTRUSION CONDITIONS

PRECONDITIONING INFORMATION:		I	II	III
Preconditioner Speed	rpm	200	200	200
Steam Flow to Preconditioner	kg/hr	0	0	0
Water Flow to Preconditioner	kg/hr	16.26	16.26	16.26
Moisture Entering Extruder	% wt	31.19	31.12	30.22
EXTRUSION INFORMATION:				
Extruder Shaft Speed	rpm	100	170	150
Extruder Motor Load	%	67	45	38
Steam Flow to Extruder	kg/hr	0	0	0
Water Flow to Extruder	kg/hr	0	0	0
Control/Temperature 1 st Head	°C			
Control/Temperature 2nd Head	°C	20/16	20/19	15
Control/Temperature 3 rd Head	°C	20/16	20/18	15
Control/Temperature 4 th Head	°C	65/65	75/75	80/80
Control/ Temperature 5 th Head	°C	65/65	75/75	80/80
Control/Temperature 6 th Head	°C	65/65	75/75	80/79
Control/Temperature 7 th Head	°C	65/65	75/75	75/74
Control/Temperature 8 th Head	°C	65/65	75/75	75/74
Control Temperature 9 th Head	°C	65/67	75/75	70/67
Head/Pressure	kPs	7/0	7/0	7/0
Head/Pressure	kPa	8/5520	8/5520	8/6210
FINAL PRODUCT INFORMATION:				
Extruder Discharge Moisture	% wt	29.37	29.78	27.11
Extruder Discharge Rate	kg/hr	100	110	
Extruder Performance		Stable	Stable	Stable
Final Product Description		Starch Beads	Starch Beads	Starch Beads

- I. Potato starch 93.5% (Redisol brand) with 5% calcium carbonate and 1.5% Blendmax lecithin as processing aid.
- II. Potato starch 93.03% with 4.98% calcium carbonate and 1.99% Blendmax lecithin.
- III. Potato starch 88.50 with 10.0% calcium carbonate and 1.5% Blendmax lecithin.

TABLE 2**DRYER FORMULA**

FORMULA NUMBER:		I	II	III
Model Number				
Number of Sections				
Zone 1 Temperature	°C	76.6	76.6	76.6
Retention Time – Pass 1	min	15	15	15
Retention Time – Pass 2	min	45	45	45
Retention Tie – Cooler	min	5	5	5
Exhaust Relative Humidity	%	40	40	40

TABLE 3**PRODUCT ANALYSIS**

PRODUCT ANALYSIS NUMBER:		I	II	III
Product Moistures				
Preconditioner Discharge	%wt	31.19	31.12	30.22
Extruder Discharge	%wt	29.37	29.78	27.11
Dryer Discharge	%wt	15.62	14.9	14.14

TABLE 4
EXTRUSION CONDITIONS

RUN NUMBER:		IV	V
Dry Recipe Information			
Dry Recipe Density	kg/m ³	780	780
Dry Recipe Rate	kg/hr	583	606
Feed Screw Speed	rpm	30	27
PRECONDITIONING INFORMATION:			
Preconditioner Speed	rpm	250	250
Steam Flow to Preconditioner	kg/hr	36	36
Water Flow to Preconditioner	kg/hr	90	90
Preconditioner Discharge Temp.	°C	93	90
Moisture Entering Extruder	%wt	22.63	25.15
EXTRUSION INFORMATION:			
Extruder Shaft Speed	Rpm	228	230
Extruder Motor Load	%	49	49
Steam Flow to Extruder	kg/hr	0	0
Water Flow to Extruder	kg/hr	0	0
Control/Temperature 1 st Head	°C	38/55	38/50
Control/Temperature 2 nd Head	°C	70/80	77/77
Control/Temperature 3 rd Head	°C	80/80	86/87
Control/Temperature 4 th Head	°C	90/93	90/91
Control/Temperature 5 th Head	°C	80/77	80/79
Head/Pressure	kPs	4950	4280
Knife Drive Speed	rpm	675	
FINAL PRODUCT INFORMATION:			
Extruder Discharge Moisture .	%wt	15.16	13.93
Final Product Description		Beads	Beads

IV. Cornflour 91.49 % with 7.01 % calcium carbonate and 1.5 % lecithin

V. Riceflour 91.49% with 7.01 % calcium carbonate and 1.5 % lecithin

TABLE 5**DRYER FORMULA**

DRYER FORMULA NUMBER:		IV	V
Model Number			
Zone 1 Temperature	°C	92	90
Zone 2 Temperature	°C	100	100
Retention Time – Pass 1	min	13.9	13.8
Retention Time – Pass 2	min	15.4	15.3
Fan Speed 1	rpm	1800	1800
Fan Speed 2	rpm	1815	1800
Fan Speed 3	rpm	1805	1800
Fan Speed 4	rpm	1800	1800

TABLE 6**PRODUCT ANALYSIS**

PRODUCT MOISTURES:		IV	V
Preconditioner Discharge	%wt	22.63	25.16
Extruder Discharge	% wt	15.16	13.93

1 the extruder is less than the water level of the starch/water mixture entering the extruder.
2 In the context of the present invention, it has been appreciated that by starting at the
3 starch/water levels herein, one effectively insures that one will ultimately proceed to
4 injection molding at an adequate water level to provide for a stable melt (non-degrading)
5 and injection mold a quality starch product with improved performance characteristics.

6 Subsequent to recovery of the starch/water extrudate, optionally, the extrudate
7 may be placed into a dryer at various periods of time (see Tables 2 and 5) wherein the
8 water level of the extrudate is lowered an additional amount depending upon dryer
9 conditions. Preferably, the water level of the starch/water extrudate is lowered within the
10 range of about 15-20%, at which point the extrudate is in condition for injection molding.

11 In the step of injection molding, preferably, the injection molding technique is
12 similarly configured to reduce moisture content once again, to a final level that is at or
13 below about 20 % by weight of the starch material. However, in preferred embodiment,
14 the final level of water in the molded product is between about 5-20 % by weight, in a
15 more preferable embodiment the water level of the molded product is set to about 10-15
16 % by weight, and in a most preferred embodiment, the water level of the molded product
17 is set to about 11-14 %, or 11-13% by weight. It has been found, therefore, that by
18 sequencing the loss of water, from extrusion, to injection molding, one achieves
19 outstanding quality for the various shaped products produced in accordance with such
20 step-down in moisture levels through-out the melt processing history disclosed herein.

21 In that regard, it has been uniquely found in accordance with the present invention
22 that it is important to actually cool the initial zone or zones of the injection molding
23 machine proximate the hopper feed section to thereby significantly improve the quality of
24 the injection molded parts produced herein. This is, of course, contrary to conventional
25 injection molding practices, wherein uniform heating above the resin T_m is generally
26 applied to all zones of the injection molding apparatus.

27 Those skilled in the art will appreciate that an injection molding machine typically
28 contains a hopper feed section, a barrel and an output nozzle, including a plurality of
29 heating zones in the barrel extending from the hopper section to the nozzle. In

1 accordance therefore with the present invention, it has been found preferable to maintain
2 the temperature in the first zone adjacent the hopper at a temperature of less than about
3 65.5°C. More preferably, the first zone adjacent the hopper is set in the range of about
4 7.5-65.5°C, preferably less than about 27°C, more preferably less than about 24°C. In an
5 even more preferred embodiment, i.e., that situation wherein there is a first zone adjacent
6 the hopper, and a second zone adjacent the first zone, the temperatures of the first zone is
7 set to about 7.5-21°C, and the second zone is set to about 21-65.5°C. These temperatures
8 are most conveniently achieved by the use of cooling coils placed about the barrel of the
9 injection molding machine, said cooling coils comprising copper cooling coils with
10 circulating water.

11 In a particularly preferred embodiment, the following temperature profile has been
12 successfully applied to a standard injection molding machine: Zone 4 (closest to hopper)
13 = about 4.5-26.5°C, preferably about 7.5-21°C; Zone 3 = about 21-65.5°C; Zone 2 = about
14 65.5-149°C; Zone 1 = about 135-190.5°C; Nozzle = about 135-199°C. In addition,
15 bushing (inside the mold) is preferably set at about 149-218.3°C. The mold temperature
16 is preferably set at about 1.4-18.4°C.

17 The advantage of the above unique temperature profile, is that as opposed to the
18 conventional practice of heating the barrel of the screw to melt the material in the zones
19 proximate the hopper, the barrel is cooled at such regions to prevent the starch material
20 from over-heating and burning. Those skilled in the art will recognize that in the case of
21 preparing a high-quality injection molded starch product, burning has been a pervasive
22 problem. Accordingly, unique to the invention herein, it has been appreciated that such
23 over-heating and burning can be regulated by an injection molding heating zone profile
24 that actually cools the barrel of the injection molding machine, thereby minimize the
25 ability of the starch to thermally degrade.

26 In accordance with the present invention, other additives can be advantageously
27 combined with the starch/water mixture to further improve the quality or strength
28 characteristics of the molded products ultimately produced. In that regard, and for the
29 purpose of preparing a pet chew toy, it has been found desirable to add attractants such as

1 chicken powder, liver powder, ham, turkey, beef and/or fish in an amount of from about
2 1.0 - 5.0 % by weight.

3 For example, once a molded product is prepared in accordance with the present
4 invention, it has also been found that over time, the water may actually migrate out of the
5 starch, thereby making the starch more brittle, which, of course, would be unsuitable in
6 the case of a pet chew toy. However, by the addition of a humectant, a compound
7 additive which retains water in the material even in the presence of heat, the products
8 herein will remain more ductile over longer periods of time. A particularly preferred
9 humectant is oat fiber, and the levels of such humectant are advantageously in the range
10 of 0.1-5.0 %, more preferably, 0.5-3 %, and in a most preferred embodiment, 0.5-1.0 %.

11 The various pet chew toys made in accordance with the present invention have
12 been found, for example, to be popular with dogs, by virtue of its chewability and
13 consistency, and improved mechanical properties. As the dog chews on the product,
14 small sections of the product become dislodged, thereby providing the animal with the
15 nutritional benefit of the components contained therein. In accordance therefore with the
16 present invention, additives such as vitamins may be added to the product, either during
17 extrusion or injection molding.

18 A preferred dog chew of the present invention is prepared from a potato starch
19 product sold under the trademark PARAGON 1010IM by AVEBE, of Veendam, The
20 Netherlands. The PARAGON 1010 IM is sold in the form of thermoplastic granules
21 which can be molded in accordance with the novel injection molding processing
22 conditions disclosed herein, which, as noted above, operates under conditions wherein the
23 zone or zones proximate to the hopper are actually cooled, as opposed to heated. In such
24 preferred formulation, the starch is present at about 70 %, the water is at about 15 %,
25 along with 5-10 % calcium carbonate and 1-5 % natural vegetable additive. That calcium
26 carbonate has been found to increase the hardness of the products produced therefrom.

27 This invention has been set forth in detail, but it should be understood by those
28 skilled in the art that the various example herein are by way of illustration only.
29 Modifications and variation will therefore be apparent and may be resorted to without

- 1 departing from the spirit and equivalent scope of this invention. Accordingly, such
- 2 modifications and equivalents are considered to be within the purview of scope of the
- 3 invention as set forth in the following claims:

1 **Claims:**

2 1. A process for forming starch into a molded article using melt processing
3 techniques which process comprises:

4 (a) combining starch and water to form a mixture wherein the water content is
5 in the range of about 20.0 to 40.0 % by weight with respect to that of said starch

6 (b) introducing and heating said mixture in an extruder wherein the water
7 content of said mixture upon discharge from said extruder is less than the water content
8 of said mixture entering said extruder; and

9 (c) introducing the extruded mixture of (b) to a heated injection molding
10 machine and injection molding and cooling to form said molded article wherein the water
11 content of said molded article is at or below about 20 % by weight.

12 2. The process of claim 1, wherein the extruder is a vented barrel extruder.

13 3. The process of claim 1, wherein the injection molded machine is a vented
14 barrel injection molding machine.

15 4. The process of claim 1, wherein the injection molding machine contains a
16 vented mold.

17 5. The process of claim 1, further comprising the step of introducing the
18 product of step (b) to a dryer and reducing the water content to a level less than that of the
19 water content of said product discharged from said extruder.

20 6 The process of claim 1, wherein said water content in step (a) is about 25-
21 35 % by weight.

22 7 The process of claim 1, wherein said water content in step (a) is about 30-
23 35 % by weight.

24 8 The process of claim 1, wherein said water content in step (a) is about 30-
25 33 % by weight.

26 9 The process of claim 1, wherein the water content of said molded article is
27 about 5-20 % by weight.

28 10. The process of claim 1, wherein the water content of said molded article is
29 about 10-15 % by weight.

1 11 The process of claim 1, wherein the water content of said molded article is
2 about 11-14 % by weight.

3 12. The process of claim 1, wherein the water content of said molded article is
4 about 11-13 % by weight.

5 13. The process of claim 1, wherein the water content in step (a) is about 25-
6 35 % by weight, and the water content of said molded article is about 10-15 % by weight.

7 14. The process of claim 1, wherein during step (c), 1-5 % of an attractant and
8 0.1-5% of a humectant are added to said extruded mixture.

9 15. A process for forming starch into a molded article using melt processing
10 techniques which process comprises:

11 (a) combining starch and water to form a mixture wherein the water content is
12 in the range of greater than about 20.0 to about 40.0 % by weight with respect to that of
13 said starch

14 (b) introducing and heating said mixture in an extruder wherein the water
15 content of said mixture upon discharge from said extruder is less than the water content
16 of said mixture entering said extruder; and

17 (c) introducing the extruded mixture of (b) to a heated injection molding
18 machine and injection molding and cooling to form said molded article wherein the water
19 content of said molded article is at or below about 20 % by weight, wherein the injection
20 molding machine contains a hopper feed section, a barrel and an output nozzle, including
21 a plurality of heating zones in said barrel extending from said hopper section to said
22 nozzle, wherein said heating zone in said barrel adjacent said hopper is maintained at a
23 temperature of less than about 65.5°C.

24 16. The process of claim 15, further comprising the step of introducing the
25 product of step (b) to a dryer and reducing the water content to a level less than that of the
26 water content of said product discharged from said extruder.

27 17. The process of claim 15, wherein said barrel adjacent said hopper is
28 maintained at a temperature of less than about 38°C.

1 18. The process of claim 15, wherein said barrel adjacent said hopper is
2 maintained at a temperature of less than about 24°C.

3 19. The process of claim 15, wherein said barrel adjacent said hopper is
4 cooled to a temperature of between about 4.4-26.7°C.

5 20. The process of claim 15, wherein said cooling to form said molded
6 product takes place in a mold cooled to about 1.6-18.4°C.

7 21. A process for forming starch into a molded article using melt processing
8 techniques which process comprises:

9 (a) combining starch and water to form a mixture wherein the water content is
10 in the range of greater than about 20.0 to about 40.0 % by weight with respect to that of
11 said starch

12 (b) introducing and heating said mixture in an extruder wherein the water
13 content of said mixture upon discharge from said extruder is less than the water content
14 of said mixture entering said extruder; and

15 (c) introducing the extruded mixture of (b) to a heated injection molding
16 machine and injection molding and cooling to form said molded article wherein the water
17 content of said molded article is at or below about 20 % by weight, wherein the injection
18 molding machine contains a hopper feed section, a barrel and an output nozzle, including
19 a plurality of heating zones in said barrel extending from said hopper section to said
20 nozzle, wherein the first and second zones adjacent said hopper are maintained at a
21 temperature less than about 65.5°C.

22 22. The process of claim 21, further comprising the step of introducing the
23 product of step (b) to a dryer and reducing the water content to a level less than that of the
24 water content of said product discharged from said extruder.

25 23. The process of claim 21, wherein during step (c), 1-5 % of an attractant
26 and 0.1-5% of a humectant are added to said extruded mixture.

27 24. A process for forming starch into a molded article using melt processing
28 techniques which process comprises:

1 (a) combining starch and water to form a mixture wherein the water content is
2 in the range of greater than about 20.0 to about 40.0 % by weight with respect to that of
3 said starch

4 (b) introducing and heating said mixture in an extruder wherein the water
5 content of said product upon discharge from said extruder is less than the water content of
6 said product entering said extruder; and

7 (c) introducing the extruded mixture of (b) to a heated injection molding
8 machine containing a mold and injection molding and cooling to form said molded article
9 wherein the water content of said molded article is at or below about 20 % by weight,
10 wherein the injection molding machine contains a hopper feed section, a barrel and an
11 output nozzle, including a plurality of heating zones in said barrel extending from said
12 hopper section to said nozzle, wherein said plurality of heating zones are set within the
13 following temperature ranges:

14 zone 1 = at or below about 21°C.

15 zone 2 = at or below 65.5°C.

16 zone 3 = at or below 149°C.

17 zone 4 = at or below about 190.5°C.

18 25. The process of claim 24, further comprising the step of introducing the
19 extruded mixture of step (b) to a dryer and reducing the water content to a level less than
20 that of the water content of said extruded mixture discharged from said extruder.

21 26. The process of claim 24, wherein said cooling to form said molded article
22 takes place in said mold at a temperature of about 1.4-18-4°C.

23 27. The process of claim 24, wherein said mold contains a bushing heated to
24 about 149-218.3°C.

25 28. The process of claim 24, wherein said nozzle is maintained at a
26 temperature between about 135-199°C.

27 29. The process of claim 24, wherein during step (c), 1-5 % of an attractant
28 and 0.1-5% of a humectant are added to said extruded mixture.

1 30. In the process of manufacturing a molded starch/water product, the
2 improvement which comprises introducing an extruded starch pellet containing water
3 therein to a heated injection molding machine and injection molding and cooling to form
4 a molded article wherein the water content of said molded article is at or below about 20
5 % by weight, wherein the injection molding machine contains a hopper feed section, a
6 barrel and an output nozzle, including a plurality of heating zones in said barrel extending
7 from said hopper section to said nozzle, wherein the zone adjacent said hopper is
8 maintained at a temperature less than about 65.5°C.

9 31. The process of claim 30, wherein said zone adjacent said hopper is
10 maintained at a temperature between 7.5-65.5°C.

11 32. The process of claim 30, wherein said zone adjacent said hopper
12 comprises a first heating zone adjacent said hopper, and a second heating zone adjacent
13 said first zone, and the temperatures of said first heating zone is about 7.5-21°C and the
14 temperature of said second heating zone is about 21-65.5°C.

15 33. The process of claim 30, wherein during said injection molding 1-5 % of
16 an attractant and 0.1-5% of a humectant are added to said extruded mixture.

17 34. An injection molded starch product formed by:

18 (a) combining starch and water to form a mixture wherein the water content is
19 in the range of about 20.0 to 40.0 % by weight with respect to that of said starch

20 (b) introducing and heating said mixture in an extruder wherein the water
21 content of said product upon discharge from said extruder is less than the water content of
22 said product entering said extruder; and

23 (c) introducing the extruded mixture of (b) to a heated injection molding
24 machine and injection molding and cooling to form said molded starch product wherein
25 the water content of said molded article is at or below about 20 % by weight.

26 35. The product of claim 34, further comprising the step of introducing the
27 extruded mixture of step (b) to a dryer and reducing the water content to a level less than
28 that of the water content of said extruded mixture discharged from said extruder.

- 1 36. The product of claim 35, wherein during step (c), 1-5 % of an attractant
2 and 0.1-5% of a humectant are added to said extruded mixture.