Improving the Texture of Plant Based Meat

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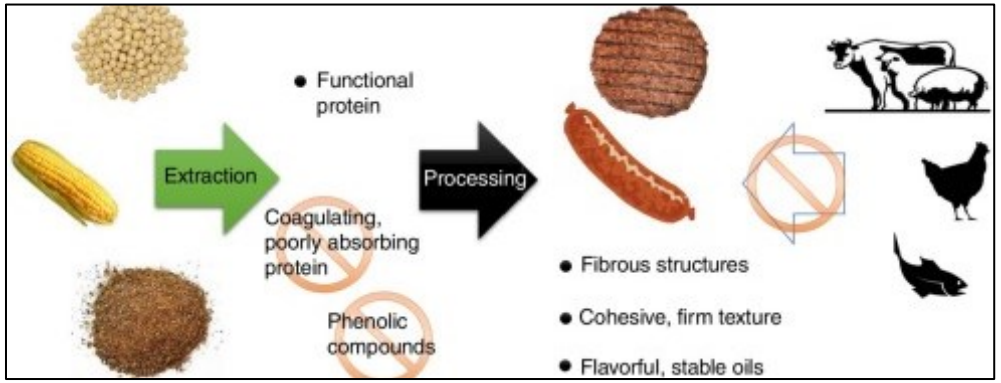
TEXTURE – A MAJOR CHALLENGE

- It is necessary to bring in the springiness of meat protein in plant-based meat. Unless treated, plant proteins will give **crumbly or mushy texture** to the product.
- Firmness (toughness or degree of tenderness), cohesiveness and juiciness are characteristics of meat, which must be replicated in plant-based meat.
- Plant-based meat is mostly prepared from textured vegetable protein fibers from soy, corn and other sources and processed with the fat phase to form meat-like structures.
- Plant sources have **higher moisture content** as compared to meat, hence they are difficult to clean and also the products are hygroscopic in nature. **Some additives such as gums or starches used in the formulations are also difficult to clean.**
- The moisture content in the starting material and temperature during extrusion play an important role in achieving the desired sensory properties of the final product.
- Plant-based meat is mostly manufactured by extrusion techniques that permit the texturization and fiber alignment of plant proteins. However, high pressure and temperatures could inactivate the anti-nutrition factors in plant proteins.



Plant-based meat from plant proteins

- Meat fat melts slowly over a wide range of temperatures, giving the product good juiciness, which, upon chewing, lingers for a long time.
- Many companies are currently using coconut oil. However, coconut **oil melts faster than meat fat**, and the **richness waves off faster**. Thus, this challenge needs to be addressed as well.
- The problems associated with texture of plant-based meats and the different solutions developed by 5 companies were sourced from their respective granted patents / patent applications.
- The best mode of invention from each of these companies has been presented in the following slides.

The Challenges

- High moisture content
- Gums or starches are difficult to clean
- Imitation of meat fat
- Oil melts faster as compared to meat fat
- Richness declines faster
- Creamy, fatty mouthfeel

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TEXTURE: SOLUTIONS PROVIDED BY FIVE COMPANIES

- SPA conducted a quick study to understand how different companies are solving the problem of texture in plant-based meat. SPA identified 5 companies and did a deep dive into how they are addressing the texture related problems. SPA has picked the best mode from the patents of these companies, and hence the report is not to be considered as a comprehensive one.
- The different solutions provided by the 5 companies (Nestle, Nissin Foods, Beyond Meat, Impossible Foods and Unilever) are summarized in the table below and the details are provided in the subsequent slides.
- The solutions provided by a few other assignees and universities are presented in the annexure.

Sr. No.	Company	Approach
1	Nestle	Gradual cooling of the heated dough with simultaneous decrease in pressure; No extrusion process.
2	Nissin Foods	Extrusion process in which extruder has square parallel blades with a clearance of 0.8 mm and cutting extrusion width of 0.4 or 0.6 mm, with provision for hot air drying at 60^{o}C.
3	Beyond Meat	The meatless composition has 24.8% water, 44.64% meat-structured protein, 1.99% taste agents, 2.18% binding agents, 24.8% agent-releasing systems and 0.99% other ingredients. Also used are nano- emulsions, binding agents and stabilizing agents for improving the texture.
4	Impossible Foods	Extrusion process, with custom-made cooling die - round, ID 6.5 mm, length 300 mm; Screw speed of the extruder - 120 RPM. Texture is also maintained by the addition of cream of tartar or any carbohydrate-based gel.
5	Unilever	Vegetable patty containing 13.2 vol.% of oil droplets having spherical diameter of >100 microns and 8.1 vol.% of oil droplets having spherical diameter of > 300 microns; Displayed visible moisture and juicy appearance.

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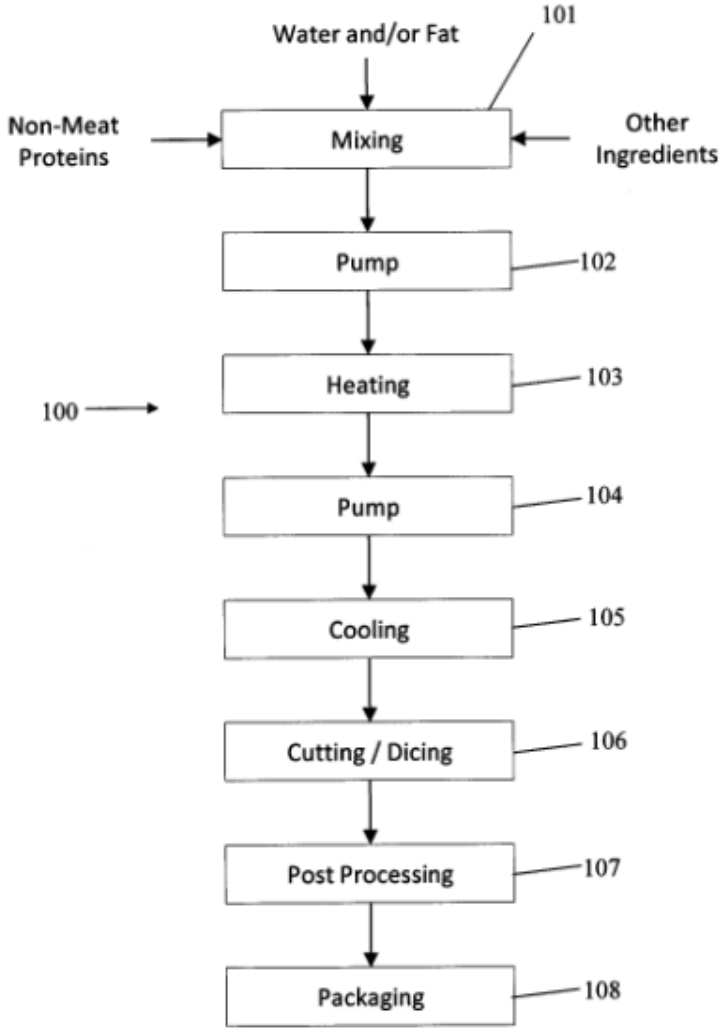
Nestle has achieved a meat-like texture without using an extruder, by gradual cooling of the heated dough with simultaneous decrease in pressure.

- Dry ingredients containing vegetable proteins are mixed with wet ingredients (water and/or oil) to form non-meat dough.
- Heated non-meat dough, mixed with gravy, gel, and/or condiment, is subjected to gradual reduction of pressure along with simultaneous cooling. The method includes pumping non-meat dough from a mixing device to a heating device, without any processing steps inbetween, while maintaining pressure on heated non-meat dough during transfer. A batch or continuous mixer is used. Heating is performed by a high shear emulsifier, heat exchanger or dielectric heater. Gradual cooling is performed by a heat exchanger.
- Non-meat dough resulting from mixing is an emulsion having moisture content of 40-67%. Dry ingredients such as starch flour and/or legume flour containing 15-45% wheat gluten and wet ingredients containing 3-14% oil are then mixed with the non-meat dough. Oil is selected from among soybean oil, corn oil, sunflower oil, high oleic sunflower oil, olive oil, canola oil, safflower oil, peanut oil, palm oil, cottonseed oil, coconut oil, almond oil, hazelnut oil and/or grapeseed oil.
- Heating is performed at 154° C. at a pressure of 17.2 bar.
- As the heated non-meat dough travels through the cooling device, both the temperature and the pressure are gradually reduced at a predetermined rate.
- The dough has moisture and is under elevated temperature, so **moisture flashing is controlled to avoid rapid expansion of the food product**. Product expansion that **is too rapid can disrupt the structure of the texturized food product.** However, depending on the desired appearance of the final food product, some flashing may be required to reduce the temperature at the center of the food product so as to expose some of the fibers in the food product.
- The non-meat food products resulting from the above process have a strong bite/mouthfeel and are not pasty, mushy, or brittle.



Flow chart for preparation of textured non-meat food product without use of extrusion

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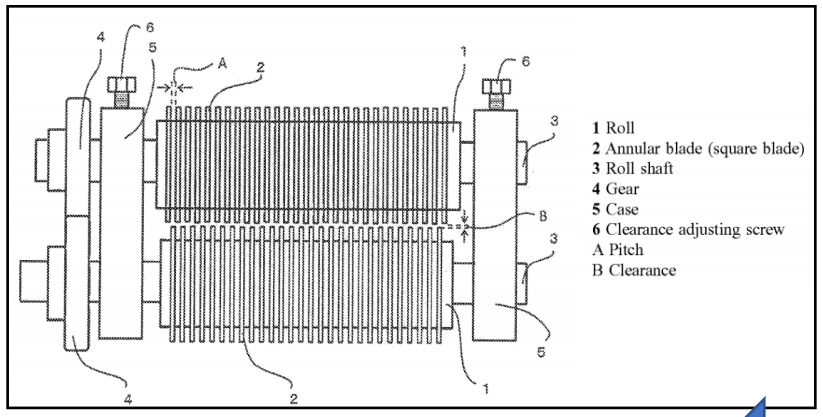
Nissin manufactures non meat-like fibrous food product using an extrusion process. The product is found to be very near to the real meat structure while having an excellent fibrous texture.

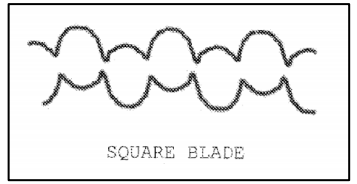
The ingredients include (by wt.%) defatted soybean (80) , separated soybean protein (10) , corn starch (9.6) and calcium sulfate (0.4). The extruder has square parallel blades with a clearance of 0.8 mm and cutting extrusion width of 0.4 or 0.6 mm, and provision for hot air drying at 60°C. This way, the moisture content is maintained at 8 wt. %. The product is soaked in water overnight and subsequently dewatered to achieve fiber alignment, following which it is cut to obtain desired size.

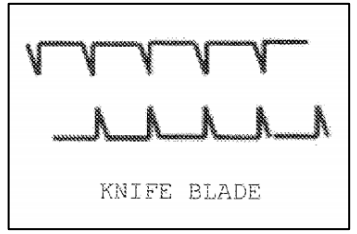
- A flat-sheet-like textured protein material having a porous structure is prepared via pressurization and heating, and then extruding using an extruder fitted with cutting blade rolls. A pair of rolls facing each other having multiple square-blade-like annular blades arranged in parallel, thereby making slits in the same direction as extrusion.
- Hot-air drying is used to control the texture.
- Raw material powder comprising defatted soybean (10 wt. % of separated soybean protein, 9.6 wt. % of corn starch and 0.4 wt. % of calcium sulfate are mixed, water is added such that it is 5 wt.% of the raw material powder, and it is contacted with 1.5 wt. % of saturated steam while kneading. (Example 1)
- The resultant material is extruded using a **biaxial extruder under** conditions of **110°C and 3.5 MPas through a slit die having a 1 mm thick and 30 mm wide outlet port,** thereby preparing a flat-sheet-like textured protein material that is cut such that the **length is about 25 mm. It is** dried in a **hot air at 60°C, such that the moisture content is 8 wt. %.**
- The effect of extrusion parameters such as pitch width and clearance width of the cutting blade rolls were evaluated, the details of which have been presented in the adjoining table in the patent document. Examples 1,3, 5 and 6 were rated as “excellent” after assessing all the test samples. Thus, products prepared with square parallel blades with clearance 0.8 mm and cutting extrusion width with 0.4 or 0.6 mm are stated to possess excellent fibrous texture.

Examples	Parameter of 1st example	Dimensions in mm
2, 3 and 4	Pitch width of the cutting blade rolls	0.6, 1.2 and 1.5 respectively
5, 6 and 7	Clearance width of the cutting blade rolls	0.4, 0.6 and 0.8 respectively

Comparative Examples	Parameter of 1st example
1	Annular blades of the cutting blade rolls replaced by pointed sharp-edged blades
2	Slits made so as to be perpendicular to the extrusion direction.
3	One of the cutting blade rolls replaced by a flat roll with no annular blade: the slits are made on only one side of the product sample.
4	Both cutting blade rolls replaced by flat rolls with no annular blade: the number of gear teeth changed so that the ratio of the rotation speed of one roll and that of the other roll is 5:3: and the sample product is pressed and flattened without making any slit thereon.
5 and 6	Pitch width of the cutting blade rolls - 0.4 mm and 2.5 mm respectively
7 and 8	Clearance width of the cutting blade rolls was 0.2 mm and 1.0 mm respectively







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Beyond meat's sample, made with 24.8% water, 44.64% meat-structured protein, 1.99% taste agents, 2.18%binding agents, 24.8% agent-releasing systems and 0.99% ingredients, scored high in sensory as well as in texture analysis. Also used are nano emulsions, binding agents and stabilizing agents for improving the texture.

- **The smaller the average size of the droplets, the tighter the droplets can be packed. This will result in a firmer texture**. The average sizes of the droplets comprised in the emulsions are between 45 nm and 75 nm.
- Texturing agents are fatty acids, and their release produce melted fat releases that are similar to those released by animal meat during cooking. Such agents could be binding agents, and their release provides a cohesiveness to meat-like consumables that is similar to that of animal meat during cooking.
- Other factors that can influence the texture of meat-like food products comprise gels, **liquid phases, stabilizing agents, and water content of the gels.**
- Eight samples were prepared with different compositions and were evaluated using different criteria. The samples that scored more in textural score had the composition mentioned at the top of the slide. The results of the sensory panel has been presented in the next slide.
- **Production and Texture Analysis of High Edible Fiber Components – Example 1**
    - A slurry of 20% by weight of *Psyllium* husk powder (5 g; ground finely in a spice grinder) and 80% by weight of water (20 g) was prepared. The slurry was spread on a hot electric griddle at 350° F to about 1-3 mm thickness, and baked for 3 min (1.5 min on each side) with constant pressure to produce a thin sheet with minimal bubbling. The baked product was cooled for 10 minutes, and then cut into 50 mm long strips with widths of either 2 mm or 10 mm, and thicknesses ranging from 1.5 mm to 2.5 mm (n=6 for 6 mm width; n=7 for 10 mm width)3.
    - Samples were analyzed with a WBS blade (about 1 mm) on a TA.XT Express Texture analyzer (Stable Microsystems, UK) with a pre-test speed of 5 mm/sec, test speed of 5 mm/sec, post-test speed of 10 mm/sec, travel distance of 15 mm and trigger load of 10 g. WBS Hardness (g Load) and Work (g Load*sec) were measured, and averages and standard deviations were recorded for each sample type.

Continued…

Production and Texture Analysis of Meat-Structured Protein Products – Example 2

- A dry mix of composition 98.5% by weight pea protein isolate 1% by weight of potassium bicarbonate and 0.5% by weight of calcium hydroxide was blended for 5 minutes in a ribbon blender.
- The dry ingredient blend was transferred to the hopper of a gravimetric feeder that metered the blend through the feed port of a twin screw extruder at 50a rate of 8.2 kg/h.
- At the same time, a liquid mix was channeled from a water tank through an in-line water heater that kept the water temperature fixed at 21.1° C., and was pumped via a gear pump through the liquid feed port of the twin screw extruder at 7.6 kg/h.

Analysis of Meat-Like Food Product Comprising a Lipogel as an Agent Release System – Example 6

- Texture Profile Analysis (TPA) samples were portioned into 113 g spheres and formed into patties by compressing the sphere to a thickness of 22 mm.
- The samples were analyzed either immediately or individually vacuum sealed, frozen at −20° C., warmed to 4° C. in a refrigerator, and analyzed within 3 minutes of removal from the refrigerator.
- TPA was performed using a TA.XT Express Texture Analyzer and a polymethylmethacrylate cylinder probe of 25 mm di-diameter.

Sensory experts' comments on the uncooked meat-like food products were ‘extraordinary’.

Results of Sensory Panel Evaluation

Uncooked	Appearance	Aroma	Texture	Quality
FB12	9.7	7.2	8.3	8.5
FB17	8.5	6.7	9.5	8.3
FB18	8.8	6.8	9.2	8.7
FB19	7.8	6.5	6.5	6.8
80/20 Ground Beef	12.8	12.7	12.3	12.7
90/10 Ground Beef	12.8	12.3	12.2	12.7

Cooked	Appearance	Aroma	Texture	Quality	Flavor Balance
FB12	9.3	7.7	8.2	8.3	6.8
FB17	10.5	8.8	10.2	9.2	9.0
FB18	10.0	8.7	8.8	8.2	7.2
FB19	7.7	7.2	8.2	7.8	7.7
80/20 Ground Beef	8.8	8.7	7.5	7.7	6.8
90/10 Ground Beef	9.7	9.3	9.0	9.2	8.8

Sensory results of the samples

Springiness=(Time-diff4:5/Time-diff1:2);

Cohesiveness=(AreaFT4:6/AreaFT1:3);

Hardness=Forcel;

Gumminess=(Hardness×Cohesiveness);

Chewiness=(Springiness×Gumminess); and

Resilience=(Area FT2:3/Area FT1:2);

Texture Analyzer results of the sample

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Impossible Foods manufactured plant-based products that mimic ground meat including the fibrousness, heterogeneity in texture and other properties, by using an extrusion process (custom-made cooling die - round, ID 6.5 mm, length 300 mm: screw speed of the extruder - 120 RPM). It was observed that the texture depended on the edible fiber component and its fibrousness and tensile strength. Texture was also maintained by the addition of cream of tartar or any carbohydrate-based gel.

- The texture of the ground meat product (e.g., meat patty) depends on properties of the edible fibrous component such as fibrousness and tensile strength. The extruded mixture of isolated plant proteins or solution spun protein fibers can be referred to as connective tissue replicas and the fibrousness and tensile strength of the connective tissue replicas can be controlled by co-variation of extrusion parameters such as temperature, throughput, and die size. For example, combinations **of lower extrusion temperatures, medium/low throughputs and smaller dies favor production of highly fibrous tissues with low tensile strength**, while higher extrusion temperatures, higher throughputs and larger dies favor production of low fibrousness tissue replicas with very high tensile strengths.
- The fibrousness and tensile strength of connective tissue replicas also can be modulated by changing the composition of the extrusion mixture**.** For example, by increasing the ratio of isolated plant protein (e.g., soy protein such as conglycinin) to wheat gluten to 3:1 w/w, and simultaneously decreasing water content in the extrusion mixture to 50%, a **connective tissue replica with thinner fibers and larger tensile strength can be made.**
- A meat dough can be heated by applying dry heat, for example, by placing in a bread maker or oven, or by **immersing in hot water or broth**. Boiling in broth can improve the meat dough flavor because beneficial flavors and off-flavor masking agents can be absorbed into the dough. **Texture properties may also be modulated by the choice of the cooking method.**
- **Dehydrins** can be particularly useful for enhancing the juiciness and texture in the ground meat replicas.
- The texture of a meat dough also can be **modified by adding cream of tartar** to the preparation. For example, meat dough preparations containing cream of tartar may be more cohesive, with a form factor after grinding that is similar to ground beef, such that it is readily shaped. Cream of tartar can be added **between 0.05% and 2.5% (e.g., 0.5%).**
- The **carbohydrate-based gels also are useful for developing the texture** of the meat replica and providing juiciness to the final product without making it soggy. Typically, carbohydrate-based gels that have a melting temperature between about 45° C. and 85° C. are used. Non-limiting examples of suitable carbohydrate-based gels include agar, pectin, carrageenan, konjac (also known as glucomannan), alginate, chemically modified agarose, or their mixtures.

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Preparation Conditions:

- A soft connective tissue replica was prepared using **soy protein isolate, Vital wheat gluten and water.** A Nano 16 extruder was used, with a **custom - made cooling die (round, ID 6.5 mm, length 300 mm**), a cooling water circulator and a high pressure water pump.
- 50 g of soy protein isolate and 50 g of wheat gluten powder were thoroughly mixed with manual mixing and tumbling for 5 min, and then loaded into the loading tube of the extruder's batch feeder. The dry mixture was fed into the extruder at the rate of 2.4 g/min. Water was fed by the pump into the second zone of the extruder's barrel at the rate of 3.6 ml/min. Screw speed of the **extruder was maintained at 120 RPM.** A temperature gradient was set along the extruder barrel as follows: Feed zone - **25° C., zone 1 - 30° C., zone 2 - 60° C., zone 3 - 110° C., zone 4 - 110° C.** The die plate was neither actively heated, nor cooled. The cooling die was cooled by the **cooling water circulator maintaining the die at 24° C.**

Assembly and Cooking of Burger (Example 11):

- Patties (Composition in table 1) were cooked on a preheated (325-345° F.) non-stick skillet and heated to an internal temperature of 160° F. while flipping every 2 minutes. Typical cook times ranged from 12 to 15 minutes. Cooked patties had an appearance, texture and flavor similar to ground beef as judged by a trained sensory panel.
- **Adipose Replica Emulsion** is stabilized by Soy Conglycinin Protein to form tissue replica that is white to slight off-white in color, solid at room temperature, with a bland and very neutral flavor and **texture characterized as similar to rendered beef fat.**

Composition of Burger

Ingredient	%
Meat dough (Example 10)	54.1
1% agar preparation	20.0
Coconut oil with flavor system (Example 6)	13.5
16x precursor mix 2 (Table 1)	5.9
RuBisCO preparation (dry) (Example 2)	5.3
LegH preparation (dry) (Example 1, *E. coli*)	1.2
Total	100

Table 1: Composition of burger (Example 11)

Continued…

Assembly and Cooking of Burger

Patties (Composition in Table 2) were cooked on a preheated (325-345° F.) non-stick skillet and heated to an internal temperature of 160° F while flipping every 2 minutes. Cooked patties had an appearance, texture, and flavor similar to ground beef stews or loaves. In addition to cooking in patty format, the unformed material can also can be used in a variety of dishes such as **taco filling , casseroles , sauces , toppings , soups , stews or loaves.**

Ingredients	%
Meat dough	26.9
Bloody agar	33.9
Flavoured emulsion	20.0
Soft connective tissue	19.2
Total	**100**

Table 2: Composition of burger in Example 27

Assembly and Cooking of Burger

Patties were cooked on a preheated (325-345° F.) non-stick skillet and heated to an internal temperature of 170° F while flipping every minute. Cooked patties had an appearance, texture, and flavor similar to ground beef In addition to cooking in patty format.

Ingredients	%
Meat dough	26.8
Fatty emulsion	20.0
Soft connective tissue	19.2
Bloody agar	13.0
Hydration liquid	10.5
Soy conglycinin, dry	10.5
Total	**100**

Table 3: Composition of burger in Example 28

Assembly and Cooking of Burger with 10% Meat Dough

Patties were cooked on a preheated (325-345° F.) non-stick skillet and heated to an internal temperature of 170° F while flipping every minute. Cooked patties had an appearance, texture and flavor similar to ground beef.

Ingredients	%
Meat dough	10.0
Fatty emulsion	20.0
Soft connective tissue	36.0
Bloody agar	13.0
Hydration liquid	10.5
Soy conglycinin, dry	10.5
Total	**100**

Table 4: Composition of burger in Example 29

Assembly and Cooking of "Taco Meat"

The mixed tissue was then cooked on a preheated (325-345° F.) non-stick skillet to 160° F. Cooked tissue had an appearance, texture, and flavor similar to ground beef.

Ingredients	%
Meat dough	29.9
Fat emulsion	22.3
Soft connective tissue	21.5
Bloody agar	14.5
Hydration liquid	10.5
Total	**100**

Table 5: Composition of burger in Example 30

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Unilever has developed a shaped vegetarian meat product that has a very attractive juicy appearance and texture. Vegetable patty containing 13.2 vol.% of oil droplets having an equivalent spherical diameter of >100 microns and 8.1 vol.% of oil droplets having an equivalent spherical diameter of > 300 microns, showed visible moisture and juicy appearance.

Addition of gums such as carrageenan as flavoring ingredients and adding oil mixture to the smoked sausage followed by mixing with medium shear gave less moist appearance and more dry/rough feel, as compared to the one prepared without addition of gums.

- According to the invention, the **appearance** of shaped vegetarian meat products, especially after cutting of the product, is greatly improved if the product comprises a **substantial amount of large oil droplets.**
- A vegetarian meat product comprising a substantial amount of large oil droplets can be produced by first preparing a proteinaceous slurry, followed by mixing said slurry with a substantial quantity of oil that contains a significant amount of solid fat. By adding the oil after the protein has been thoroughly mixed with water, **break-up of the oil droplets to less than 100 pm can be minimized because the high viscosity** of the proteinaceous slurry prevents such break-up and also not much shear is required to homogeneously disperse the large oil droplets through the proteinaceous slurry.
- In addition, the use of oil containing solid fat, when mixed with the other ingredients, offers the advantage that this oil is more viscous than oils that do not contain any solid fat. This higher viscosity also counteracts break-up of the oil into small droplets and thus facilitates preparation of a product containing large oil droplets.
- The details are given in the next slide.

Product Parameters:

- 30-80 wt.% water;
- 5-35 wt.% oil, said oil having a solid fat content at 20° C of at least 1.5%: oil contains
  - 80-98 wt.% of a liquid vegetable oil selected from among the group of sunflower oil, soybean oil, rapeseed oil, cottonseed oil, maize oil, olive oil, and combinations thereof and 2-20 wt.% of a high melting oil selected from hydrogenated vegetable oil, palm stearin, palm kernel stearin, palm mid fraction, coconut stearin, butter oil, butter stearin and combinations thereof.
- 2-25 wt.% protein selected from algal protein, bacterial protein, dairy protein, egg protein, fungal protein, plant protein, and combinations thereof;
- 0-40 wt.% of one or more particulate ingredients selected from herbs, spices, vegetables and combinations thereof.

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Smoked Sausage preparation

Example 1:

1. Half of the total amount of rapeseed oil (total 24.5 wt%) and the full amount of high melting fat i.e. fully hardened palm oil were heated, mixed for homogeneity and cooled to room temperature overnight and used the next day.
2. Protein mix (11.8.wt %): wheat protein and egg white protein; flavoring ingredients (4.5.wt.%): Herbs, spices and flavoring; colorants (0.7.wt %); and salt (0.6.wt %) are added to water and mixed in a bowl (fitted with 6 knives of 4-cut shape) along with an oil mixture.
3. This oil mixture is added and mixed at a pressure of 0.4 bars at low shear setting, at ambient temperature and until visually homogeneous
4. It is transferred into non-edible cellulose casings to obtain a sausage-shaped product.
5. Pasteurized at 85 °C for 45 minutes.
6. Dried for 90 minutes at 46 °C.
7. Smoked in a smoking chamber for 90 minutes at 46 °C.
8. After smoking the cellulose casing was removed by hand and vacuum sealed in plastic.

Comparative example A

Addition of konjac gum and some carrageenan as flavoring ingredients, and mixing with medium shear after addition of oil mixture.

Result: Comparative example A had less moist appearance and more dry/rough feel than the Example 1. Thus, addition of gums did not give the required texture of meat.

Vegetable Patty Preparation

Patty A

1. Water and isolated soy protein (10.wt %) were mixed in a Stephan mixer (electronic, standard 2 knives mixing tool) at 1000 rpm for 2 minutes at a reduced pressure of 0.1 bar.
2. Rapeseed oil (20.wt %) was added and mixed at 1000 rpm for 2 minutes at a reduced pressure of 0.1 bar.
3. Finally, chickpea flour (10.wt %) and salt (0.5.wt %) were added and mixed at 1000 rpm for 2 minutes at a reduced pressure of 0.1 bar.
4. 1 kg of this mixture was then transferred in a plastic piping and the content was extruded into a transparent polypropylene beaker (internal dimensions: diameter bottom 90 mm, diameter top 106 mm, height 130 mm), which served as casing.
5. The beaker was closed with a plastic lid and placed in a water bath at 92 ° C for 1 hour. Subsequently, the product was allowed to cool to ambient temperature.
6. Finally, the product was deposited on a plate to be cut in 1 cm thick patties.

Comparative example: Patty 1

Addition of a homogeneous blend of rapeseed oil(19.4.wt %) and high melting fat (0.6.wt %), and mixing with the water and soy protein mixture at 300 rpm instead of 1000 rpm.

Result: The inside of the vegetable patty A showed no visible moisture, and did not have a juicy appearance. In contrast thereto, the inside of **patty 1 showed visible moisture and had a juicy appearance.**

Patty A contained <0.1 vol.% of oil droplets having an equivalent spherical diameter of >100 μ, whereas **patty 1 contained 13.2 vol.% of oil droplets having an equivalent spherical diameter of > 100 μ and 8.1 vol.% of oil droplets having an equivalent spherical diameter of > 300 μ.**

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PRODUCTS

Nestlé

Awesome Burger and Grounds (Plant Based Protein):

- **Awesome burger:** Sweet Earth Enlightened Foods Awesome Burger is plant based and contains 6g of fiber and 26g of plant based protein per serving. The kosher certified, totally juicy product is free from GMO.

- **Awesome ground plant based protein:** Sweet Earth Enlightened Foods Awesome Grounds Plant Based Protein is described as totally tasty and perfect for recipes. The kosher product is said to feature a full flavor, offers 16g of protein and 4g fiber per serving, is freezable

Impossible Burger:

Impossible Burger is suggested to be used like ground beef in burgers, tacos, lasagna and all favorite recipes. It contains 19g protein, and is free from gluten, cholesterol, animal hormones and antibiotics. The kosher and halal certified product is made from plants and retails in a 12-oz. pack featuring cooking instructions and the Bioengineered logos.

IMPOSSIBLE™

BEYOND MEAT

Burger and Sausages:

- **Beyond Sausage**: According to the manufacturer, the new, meatier plant based sausage is packed with even more delicious flavor and satisfying, juicy sizzle. The kosher product contains 14g of plant protein per serving and is free from soy, gluten, and GMOs
  - **Plant-based burger**: Patty contains 20g of plant protein per serving, no soy, gluten or GMO, and contains 35% less saturated fat. It is said to allow the consumer to eat more, not less, of traditional dishes, while feeling great about the health, sustainability, and animal welfare benefits of plant protein.

Burger and Sausages:

- **Vegan Looks-Like-Chicken Burger:** Vegetarian Butcher Vegane Sieht-Chick-Aus Burger (Vegan Looks-Like-Chicken Burger) is now available. This product comprises soy based chicken burger-style patties with protein, which are said to be juicy, tender, and delicious. It can be prepared on the frying pan and grill.

- **Vegetarian Mini Roasting Sausages:** Vegetarian Butcher Vegetarische Lass-Die-Sau-Raus Würstchen Mini-Bratwürstchen (Vegetarian Mini Roasting Sausages) are described as great-tasting mini Bratwursts made from soy and a lot of protein, and are said to be perfect for any time

Unilever

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Annexure

Continued…

SOLUTIONS FROM OTHER ASSIGNEES

S. No.	Problem	Solution*	Patent	Assignee
1	Finished products should have a texture comparable to meat and meat products	Meatless meat analog- or meat product is produced by (i) chopping the fruit bodies of edible mushrooms into pieces, (ii) mixing the minced fruit bodies with further ingredients comprising at least vegetable and/or animal protein to a homogeneous production mass, (iii) filling the production mass into at least one mold, and (iv) heating.	EP3292769B1	Neuburger Fleischlos GmbH
2	**Textured vegetable protein** with a texture and flavor similar to the **texture and flavor of a piece of cooked meat** or seafood	Meat analogue can be prepared by **combining proteinaceous fibers of non-meat origin with an aqueous gelling composition that contains xanthan gum and galactomannan.**	US20200029591A1	Conopco Inc
3	Existing technologies producing **plant-based products are not able to simultaneously mimic fibrous texture** and elasticity	Manufacturing an edible microextruded product comprising > two **layers of viscoelastic microextruded elements** involves providing a composition comprising an appropriate **edible solvent, protein and an edible pseudoplastic polymer.**	WO2020030628A1	Novameat Tech
4	**Removing soy presents** challenges in the formation of products having a **desirable texture and mouth feel**	**Plant proteins such as pea and bean**, and **fruit extracts** from the families Cucurbitaceae and Solanaceae appear to produce particularly effective results.	US20190045809A1	Sunfed Ltd
5	Meat substitutes may **mimic natural** or processed meat products in **texture** and response to heating	Syrup solids may act as a humectant thereby allowing the meat substitute to retain a desired texture for a longer period of time.	US20190254309A1	Land O'Lakes Inc

* Based on patent abstract

Continued…

SOLUTIONS FROM UNIVERSITIES

S. No.	Title	Approach	Organization
1	Structuring the meat analogue by using plant-based derived composites	**Freeze structuring technique i**s able to develop a fibrous and layered structure of meat analogue.	Singapore Polytechnic
2	Understanding the protein transition: The rise of plant-based meat substitute	Textured Vegetable Protein (TVP) is produced with **low moisture cooking extrusion.** The basis of extrusion is a screw system within a barrel. In the barrel, raw materials are compressed, heated to high temperatures and conveyed through a dye/dyes in order to expand into a final shape .	Utrecht University
3	Effects of edible plant polyphenols on gluten protein functionality and potential applications of polyphenol–gluten interactions	High-molecular-weight polyphenols (tannins) cross-link gluten proteins, thereby increasing protein network density and strength. **Tannin–gluten interactions can greatly increase gluten tensile strength** in dough matrices, as well as batter viscosity and stability.	Texas A&M University
4	Partial and total replacement of meat by plant-based proteins in chicken sausage: evaluation of mechanical, physico-chemical and sensory characteristics	**Chickpea flour functions as a good barrier**, inhibiting the mass loss from the food matrix to outside and, as a result, **increasing the adhesion degree in texture of the product**.	CSIR-Central Food Technological Research Institute
5	High moisture extrusion of wheat gluten: Relationship between process parameters, protein polymerization, and final product characteristics	The **polymerization of wheat gluten induced by the formation of disulfide bonds** can be considered as one of the decisive mechanisms leading to the formation of meat analog products with **anisotropic structures.**	Karlsruhe Institute of Technology

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