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Review Article

White Paper - Plant Based Meat - Texturizing Plant Proteins

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Introduction

FAO forecasts that the global meat production needs to increase by 50% to provide quality protein for the ten billion people living on planet earth by 2050. Meat fits in a healthy diet and is a good source of essential proteins, B-vitamins and several minerals (i.e. selenium and iron). A growing world population will require in 2050 about twice more food, produced on twice less arable land. Meat production is seen as less sustainable with negatives impacts on animal welfare. There is a search for alternative proteins to replace part of the animal proteins that are currently used in abundance in the diet of most developed and affluent countries.

Good digestible proteins may be a limiting factor in the future. Protein is an important part of the human diet, and the Essential Amino Acids (EAA) (histidine, isoleucine, leucine, lysine, methionine (+cystine), phenylalanine (+tyrosine), threonine, tryptophan and valine), which cannot be synthesized *de novo*, need to be supplied through the diet. The FAO recommends that amino acids be treated as individual nutrients and that adjustments for digestibility be made when designing dietary guidelines or evaluating actual diets (Food and Agriculture Organization of the United Nations (FAO), 2013). Animal protein contains more EAA, and is of slightly higher human intestinal digestibility, than most plant-based proteins.

To meet the 2050 challenge of feeding a rapidly growing human population, it is essential to carefully consider how to produce enough protein. To help consumers reduce their meat consumption, several strategies have been developed:

One strategy is encouragement of ‘meatless days’ or smaller portion sizes.

As a second strategy, meat in a meal can be replaced by the consumption of vegetables, beans, pulses, and/or nuts. In processed meat products, it can be replaced by using plant-based meat extenders as well [1]. Meat extenders are plant-based ingredients that act as fillers in processed meats. By doing so, the actual meat content in the product is lowered, leading to reduced meat intake.

A third strategy is based on the development of structured vegetable protein products. Examples of traditionally structured products are tofu and tempeh, which are produced and consumed in East Asia for centuries. The consumer acceptance of these products is, however, lower in Western countries. Therefore, another category of structured products has emerged, referred to as meat analogues. Meat analogues are products that can replace meat in its functionality, being similar in product properties/sensory attributes, and that can also be prepared by consumers as if they were meat. The resemblance of these products to meat, in terms of texture, taste, appearance, and smell, is important for consumers that currently mostly choose meat [2].

At the moment a large number of textured vegetable proteins have already entered the market as meat analogues and substitutes. Textured structures based on soy proteins were one of the first to enter the market. At the moment there are textured vegetable proteins based on (mixtures of) pea, wheat, carrot, sunflower, onion etc. The main issue with vegetable based alternative proteins are the texture and taste of the final products. Producing steak like structures is possible with textured proteins. Most off flavours can be masked by spices and taste ingredients.

In this white paper the current state of the art of the technical production processes of plant- based proteins, with special focus on the texturizing processes, will be described. This will include the established techniques that have been operated on commercial scale, and novel techniques that are less mature.

Texturizing Plant Proteins

There are several strategies to mimic the texture of meat, which depends on the type of meat product that one wants to mimic. Meat products can be categorized in ground, comminuted and whole muscle meat products. The growing range of ingredients that are used for this purpose, the range of products that are produced with these ingredients, and their nutritional value have been summarized in several review papers [3,4].

Texturizing techniques should create the fibrous structure similar to meat muscles. The various techniques follow either a bottom-up or a top-down strategy to create the fibrous morphology (Figure 1). The bottom-up strategy generates smaller structural elements that are subsequently assembled into larger products. The top-down strategy creates fibrous products by structuring biopolymer blends in which the fibrousness of the product becomes apparent when stretching the material, mimicking the structure on larger length scales only.

From a structural point of view, the bottom-up strategy has the potential to mimic meat most closely, whereas from a process design point of view, top-down strategy is more robust, scalable and have better resource efficiency.

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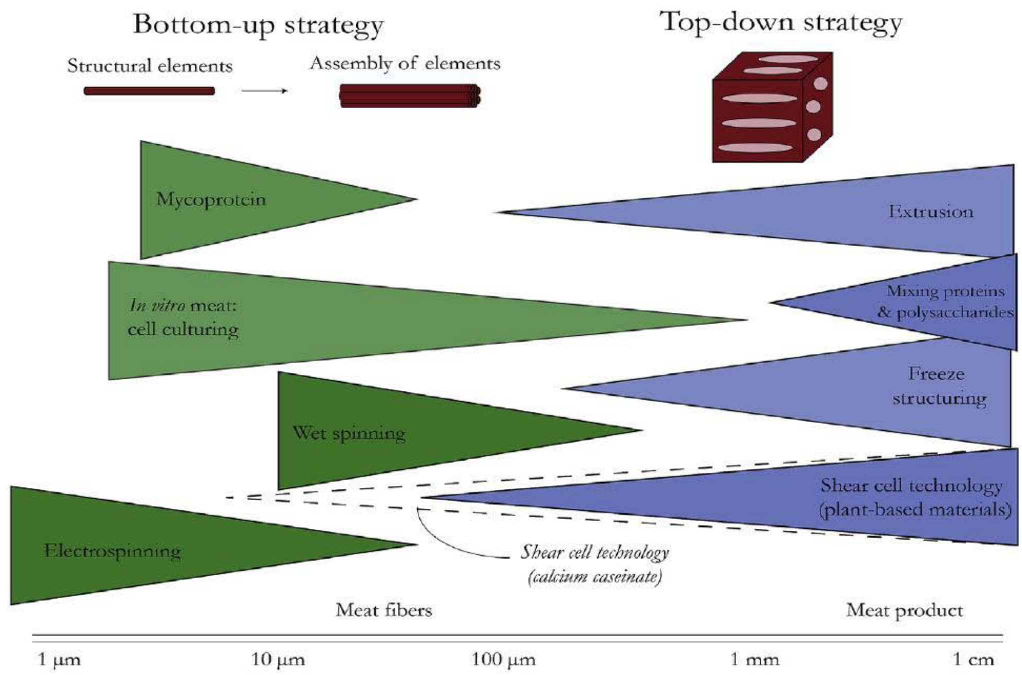

Figure 1: Bottom-up and top-down strategy to create fibrous products for the application of meat analogues [13].

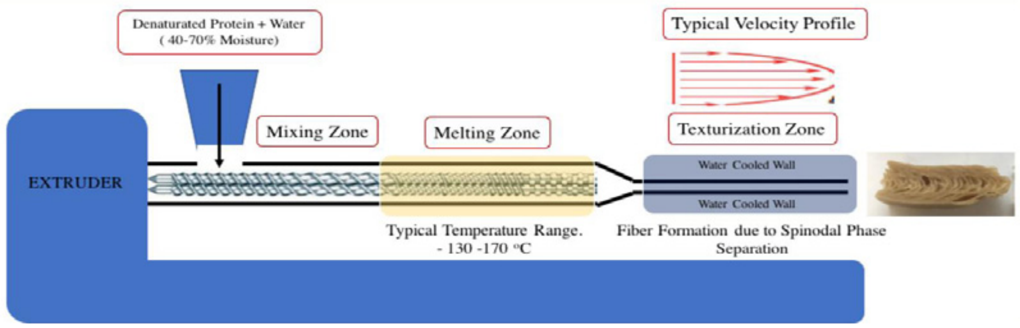

Figure 2: Basic set up of extrusion to develop meat analogues [14].

Texturizing of plant proteins involves top-down strategies that form larger structures. The most commonly techniques used in top-down strategies are:

- Low Moisture Extrusion - Textured Vegetable Proteins (TVP)
- High Moisture Extrusion (HME)
- Shear-Cell Technology

Extrusion

Extrusion is the most commonly used commercial technique to transform plant-based materials into fibrous products. There are two classes of structuring with extrusion: low-moisture and high-moisture. In low-moisture extrusion, flours or concentrates are mechanically processed into Texturized Vegetable Proteins (TVP), which are dry, slightly expanded products that are moisturized afterwards. In high moisture extrusion, fibrous products are produced with moisture contents above 50 wt%. The proteins are plasticized/molten inside the barrel by a combination of heating, hydration and mechanical deformation. When this protein-'melt' flows into the die, it gets aligned by the (inhomogeneous) laminar flow and is cooled to prevent expansion.

The basic set-up of the extrusion procedure with the different process conditions is described in Figure 2. During high-moisture extrusion cooking, the plant-based protein, water and other ingredients are separately fed to an extruder barrel and adjusted to moisture contents of 40% up to 70% [5]. In following cooking zone the protein melts at a typical temperature range of 130°C and 170°C under high shear and pressure conditions. At the extruder end, one of the key elements for the formation of the fibrous structure is the cooling die, which is required to bring the temperature below the critical temperature of the viscous protein melt. This zone of the extruder is texturization zone where the fibre formation happens with the spinodal phase separation as depicted in Figure 2.

The launch of meat analogues started with the production of dry Texturized Vegetable Protein (TVP), which is produced by cooking


Figure 3: Example of structured protein produced by high moisture cooking extrusion and twin screw extruder with opened barrel [8].

Figure 4: Basic processing flow of texturized plant protein production using POWERHEATER™ equipment.

extrusion of usually defatted soy meal, soy protein concentrate or wheat gluten [6]. These products have an elastic and somewhat spongy texture that is utilized favourably in patties, stews and sauces.

Research on the high moisture cooking extrusion process at the beginning of the 1990s led to new possibilities for texturing food proteins into distinctive fibrous structures to mimic muscle meat. This process produces in one step a fibrous, muscle meat-like structure that has a similar moisture level to meat and mimics its bite and mouth-feel [7].

Plant and animal-based proteins need to unfold, cross-link and align themselves to form microscopic and macroscopic fibers. The high moisture cooking extrusion process, which is characterized by water levels up to 70 percent, provides the required process conditions. Co-rotating twin screw extruders equipped with long screws and specially adapted long cooling dies proved to be effective for processing the low viscosity mass into a protein strand with a distinctive fibrous structure (Figure 3). In a first step the ingredients, in particular food protein powders and water, are continuously fed into a long extruder barrel. The co-rotating screws mix the ingredients thoroughly while the mass is steadily heated to temperatures of 130-180 °C and is moved towards the die section. During the hydrothermal treatment, the proteins unfold and form new covalent intermolecular bonds.

Once the mass enters the cooling die section, drag and shear flows align the proteins in the flow direction. The strong cooling in the long die section has several effects. The temperature gradient from the core of the strand to the die wall increases the shear flow, effects the cooling of the mass to a core temperature below 100°C and avoids product expansion caused by evaporation of superheated water. Along with the cooling, non-covalent hydrogen bonds, electrostatic interactions and van der Waals interactions develop. The viscosity rises and the mass solidifies to a strand with a meat-like structure [8].

The processing of meat analogues in such cooking extruders involves a multitude of machine and process parameters. Furthermore, the composition of the matrix, the variety of ingredients and the water content has a major effect on the final product. However, literature data about the individual impacts of each parameter and their interactions on fibre formation and the final product quality are scarce and are limited to soy, wheat and pea protein. High protein levels in the recipe and the use of proteins with an adequate cross-linking capability have been shown to be favourable [7,9].

Soy protein and wheat gluten have been the dominant raw materials for meat surrogates for a long time. Over recent decades, protein products from other plant based raw materials such as peas, chickpeas, lupins, rice, maize and canola have been developed in food grade quality. Additionally, protein products from animal-based sources such as milk and eggs and from new sources such as fungi and bacteria are available nowadays. All these proteins have unique techno-functional, taste and nutritional properties depending on their origin and how they are processed. The use of new proteins and, in particular, the use of new combinations offer a wealth of opportunities for creating improved and new meat analogue properties and taste sensations. Whether materials/ingredients can be extruded depends on the ratio of soluble and insoluble components; too many insoluble components disturb protein cross-linking and

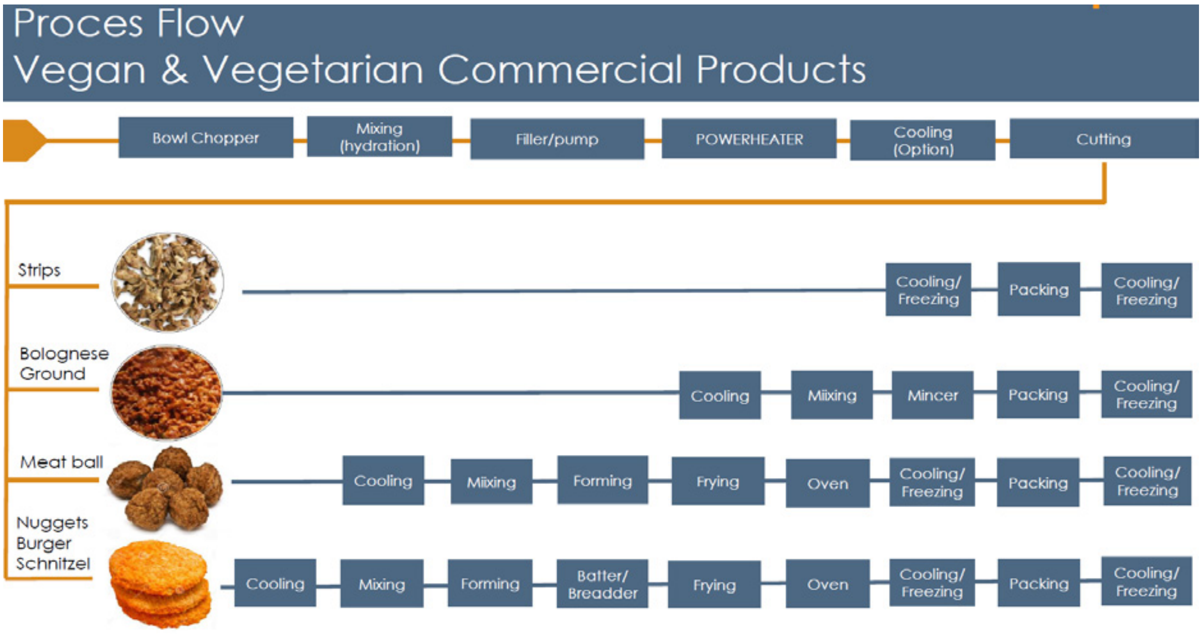

Figure 5: Processing flows of different plant based texturized product using a POWERHEATER™.

result in incoherent products. Although extrusion processing has been studied extensively for many years, the control over the process and the design of extruded products is still mostly based on empirical knowledge [10].

Shear Cell Technology

Based on the recognition that extrusion is an effective, but not a well-defined process, a technology based on well-defined shear flow deformation was introduced a decade ago to produce fibrous products. Shearing devices inspired on the design of rheometers [11], so called shear cells, were developed in which intensive shear can be applied in a cone-in-cone or in a couette geometry. The final structure obtained with this technique depends on the ingredients and on the processing conditions. Fibrous products are obtained with calcium caseinate and several plant protein blends, such as soy protein concentrate, Soy Protein Isolate (SPI) - Wheat Gluten (WG), and SPI - pectin. The structures prepared with calcium caseinate showed anisotropy on a nanoscale, while for the plant-based material, anisotropy was observed up to the micrometre-scale. The technology was successful up to pilot scale [12]. There are no large-scale shear cell technology production devices available, even though this technology scores higher than accessible extrusion technology in terms of energy input (25-40%). Various partners (WUR, Unilever, Givaudan, etc.) are working on the practical application of this technology in the 'Plant Meat Matters' project, which is hoping to bring a new generation of meat substitute products closer [15,16].

Current Commercial Texturing Equipment

A draw back of the currently available texturizing equipment is the production capacity in terms of kg product per hour. There are currently two type of extrusion-based processing equipment available that can produce up to or more than 400kg of texturized product per hour.

Clextral Equipment in France produces traditional twin-screw extrusion systems with state-of-the-art solutions for the continuous processing of plant-based proteins of homogenous quality. The twin-screw extrusion technology is used for the production of cereals, flakes, savoury snacks, breadcrumbs, flours, proteins, flavours, pasta, couscous, pet food and fish feed. One extruder can produce texturized plant proteins continuously at 400kg per hour. The maximum width, however, of the texturized products is 10cm.

A newer and promising equipment is the PowerHeater technology (POWERHEATER™, Denmark) that can be used in line to produce texturized plant proteins that can be chilled, and either be packed as a finished product or used in further processed product or ready meals (Figure 4 and 5).

This equipment can be used in continuous system and bought with either 1, 3, or 5 screws. Each screw can produce up to 500 kg product per hour. The system can use less carbohydrates binding the texturized proteins. One of the negative aspects is that each screw has to be cleaned after one hour of production, which will reduce the overall production capacity per hour.

Conclusions

- Plant based texturized proteins are already in the market and the texture and taste is improving compared with the past.

- Animal protein contains more essential amino acids, and is of slightly higher human intestinal digestibility, than plant-based proteins.

- Initial texturized products were based on soy but currently there is a wide variety of plant proteins used in different type of textured meat analogues.

- Extrusion is the most commonly used commercial technique to transform plant-based materials into fibrous products.

There are two classes of structuring with extrusion: low-moisture and high-moisture. In low-moisture extrusion, flours or concentrates are mechanically processed into Texturized Vegetable Proteins (TVP), which are dry, slightly expanded products that are moisturized afterwards. In High Moisture Extrusion (HME), fibrous products are produced with moisture contents above 50 wt.%.

- Shear cell technology is being developed and would require less energy compare to extrusion. There are no large-scale shear cell technology production devices available, and it has only been successful up to pilot scale.

- A draw back of the currently available texturizing equipment is the production capacity in terms of kg product per hour. Until recently there were two type of extrusion-based processing equipment available that can produce up to or more than 400kg of texturized product per hour (Clextral and PowerHeater).

- Bühler Group recently (February, 2021) has launched the PolyCool 1000, a high-performance cooling die in combination with an extruder. With the PolyCool 1000, it is possible to produce wet-textured proteins based on a wide range of raw materials including soy, pulses, oilseeds, upcycled side streams like brewer spent grains, as well as newer ingredients such as microalgae, at throughputs of up to 1,000 kilograms per hour.

References

1. Boland MJ, Rae AN, Vereijken JM, Meuwissen MPM, Fischer ARH and MAJS, van Boekel. The future supply of animal-derived protein for human consumption. Trends in Food Science & Technology. 2013; 29: 62-73.

2. Hoek AC, Luning PA, Weijzen P, Engels W, Kok FJ and C de Graaf. Replacement of meat by meat substitutes. A survey on person-and product-related factors in consumer acceptance. Appetite. 2011; 56: 662-673.

3. Asgar MA, Fazilah A, Huda N, Bhat R and AA Karim. Nonmeat protein alternatives as meat extenders and meat analogs. Comprehensive Reviews in Food Science and Food Safety. 2010; 9: 513-529.

4. Bohrer BM. Review: Nutrient density and nutritional value of meat products and non-meat foods high in protein. Trends in Food Science & Technology. 2017; 65: 103-112.

5. Murillo J, L Sandoval, et al. Towards understanding the mechanism of fibrous texture formation during high-moisture extrusion of meat substitutes. Journal of Food Engineering. 2019; 242: 8-20.

6. Kinsella JE. Functional properties of proteins in foods. A survey. CRC Critical Reviews in Food Science and Nutrition. 1978; 1: 147-207.

7. Akdogan H. High moisture food extrusion. Int. J. Food Science and Technologies. 1999; 34: 195-207.

8. Wild F, Czerny M, Janssen AM, Kole APW, Zunabovic M and KJ Domig. The evolution of a plant-based alternative to meat. From niche markets to widely accepted meat alternatives. Agro Food Industry Hi Tech. 2014; 25: 45-49.

9. Lin S, Yeh CS and S Lu. Extrusion process parameters, sensory characteristics, and structural properties of a high moisture soy protein meat analog. J. Food Sci. 2002; 67: 1066-1107.

10. Emin MA and HP Schuchmann. A mechanistic approach to analyze extrusion processing of biopolymers by numerical, rheological, and optical methods. Trends in Food Science & Technology. 2017; 60: 88-95.

11. Manski JM, van der Goot AJ and RM Boom. Advances in structure formation of anisotropic protein-rich foods through novel processing concepts. Trends in Food Science & Technology. 2007; 18: 546-557.

12. Krintiras GA, Gadea Diaz J, van der Goot AJ, Stankiewicz AI and GD Stefanidis. On the use of the Couette Cell technology for large scale production of textured soy-based meat replacers. Journal of Food Engineering. 2016; 169: 205-213.

13. Dekkers BI, RM Boom and AJ van der Goot. Structuring processes for meat analogues. Trends in Food Science & Technology. 2018; 81: 25-36.

14. Navneet SD and M Dwivedi. Structuring meat analogues using extrusion: An insight. EC Gastroenterology and Digestive System. 2019; 6: 29-31.

15. Mattick CS, Landis AE, Allenby BR and NJ Genovese. Anticipatory lifecycle analysis of in vitro biomass cultivation for cultured meat production in the United States. Environmental Science & Technology. 2015; 49: 11941-11949.

16. Smetana S, Mathys A, Knoch A and V Heinz. Meat Alternatives: Life cycle assessment of most known meat substitutes. International Journal of Life Cycle Assessment. 2015; 20: 1254-1267.