THE ULTIMATE MEAT SUBSTITUTES GUIDE

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INTRODUCTION

An Environmental Challenge

With the world's population increase and relative rise of the living standards in developing countries, global meat consumption continues to grow (consumption has more than doubled in the last 50 years). To satisfy this expanding demand, industrial livestock production has multiplied, leading to discussions about the environmental, ethical and health consequences of such large-scale consumption.

The environmental impact of this production escalation is indisputable: emissions of greenhouse gases (methane and nitrogen monoxide), water pollution, deforestation.... From a health standpoint, excessive consumption of meat can lead to problems such as cardiovascular disease and colorectal cancer (for red meat), among others. There are also ethical questions of livestock welfare and the use of edible plant resources for animal feed: 44% of the worldwide cereal-cultivated land and 33% of the total worldwide cultivated land is used to feed lifestock. In total, 70% of arable lands worldwide are directly or indirectly dedicated to the breeding/farming of animals to feed humans.

ONE OF THE **MAJOR CHALLENGES OF THE 21ST CENTURY** WILL BE FEEDING THE GROWING GLOBAL POPULATION, TAKING INTO ACCOUNT SOCIETAL CONSTRAINTS SUCH AS **ENVIRONMENTAL PROTECTION AND ANIMAL WELFARE**.

Proven Trends in flexitarism

This has led to a new trend of consumption known as flexitarism. Aware of the societal and environmental effects of an animal-based diet, flexitarians are willing to reduce their meat consumption by introducing non-animal protein sources into their diets. Flexitarien consumers are defined as regular meat-eaters, environmental conscious and looking for healthy alternatives to the traditional meat products.

Mankind being omnivorous, we can anticipate that the global population will still, on average, include meat in its diet. However, some of this consumption of meat products could be replaced by another type of high protein food: meat substitutes.

MEAT SUBSTITUTES

New Generation of Meat Substitutes

Meat substitutes are plant-based products that have the protein content, appearance and taste of real meat, meat-like textures, and highly beneficial compositions containing essential amino acids with low or no cholesterol. Their production does not cause large-scale ethical or environmental impacts.

Vegetable meats (or meat analogues) have been produced for decades but found limited commercial success. Yet a new generation of meat replacements developed with improved ingredient and process technology is increasingly in demand today by European and American consumers.

The new generation of meat substitute or meat analogue match specifically the characteristics of meat texture. It now is also possible to modulate colour, using natural colourings, and flavour, with aromas or spices.

Soja

Lupine

Chickpeas

Raw Materials for Meat Substitutes Production

Meat substitutes are made of fibrated proteins. Fibrated proteins are vegetable proteins that are cholesterol-free, low in fat, high in protein and fiber content, and rich in nutrients. The proteins are directly extracted from plants such as soya, cereals, or pulses (peas and beans) or other plants. They can also integrate fish or meat-based raw materials, for human or animal consumption.

Plant proteins are widely available and allow preparations of various compositions including vegetarian and vegan products. Among the main sources of plant proteins we can cite: wheat gluten, soya bean, pea, lentil, fababean, chickpea, common bean, and lupine.

Protein sources can be used in different forms: Isolate, concentrate, defatted flour, and even full fat flour, providing adequate equipment configuration. They can be mixed with additional ingredients to bring different functionalities, texture and mouth feel.

PROTEIN FIBRATION

Protein Fibration by Twin Screw Extrusion

Extrusion-cooking has been described as a new method of continuous cooking of starchy and proteinaceous foodstuffs.
As a High Temperature Short Time (HTST) process it favors mechanical action for the conversion of starches and proteins. Largely used with low moisture content (< 30% wwb), cooking-plasticizing of starchy and proteinaceous materials is intended to give the resulting products a specific texture, typically expanded, shaped or texturized, for a sensory or functional purpose (physical end-use properties).

THIS NEW GENERATION OF MEAT SUBSTITUTE IS PRODUCED THANKS TO TWIN SCREW EXTRUSION PROCESS

In the early 1980s, a new extrusion-cooking process was developed consisting of plasticizing food mixes at high moisture content ranging from 50% to 80%.

This process was first applied to emulsify and prepare gel cheese analogues or to prepare fat substitutes and was later extended to texturize proteins into meat analogues.

The work studies made by two researchers A. Noguchi, working from the National Food Research Laboratory in Tsukuba (Japan), and J.C. Cheftel, in the Laboratory of Biochemistry and Food Technology at The University of Montpellier (France), particularly contributed to create the new innovative process of High Moisture Extrusion Cooking, also called Protein Fibration Technology.
These food scientists successfully created meat-like textures from soy ingredients using twin screw extrusion (Nogushi, 1989).

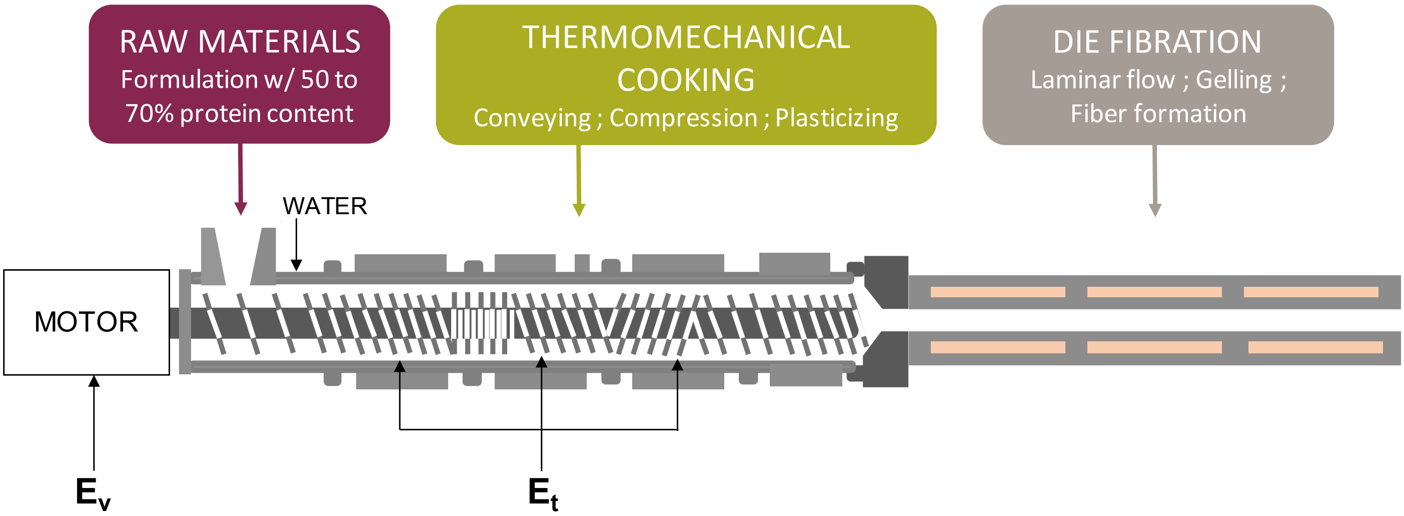
Later, the process was successfully scaled-up and industrialized by CLEXTRAL, who was granted a patent for the process in France in 2001.

The process of protein fibration combines two main unit operations (Bouvier, 2006):

Thermomechanical cooking and product fibration.

Thermo-mechanical cooking of protein in protein fibration process does occur in a complex screw-barrel assembly of the twin screw extruder, which includes specific screw profile with high L/D ratio (Length/Diameter), and high moisture content (generally between 50 and 70 % wwb).
Temperatures in the range of 130 – 160 °C and relatively long residence time are required to obtain fiber formation. Protein fibration process includes a second device, a long cooling die.

In the case of fibration technology, this long cooling die, plays a key role in the mechanism of protein fibration :



What happens in the twin screw extruder and die ?

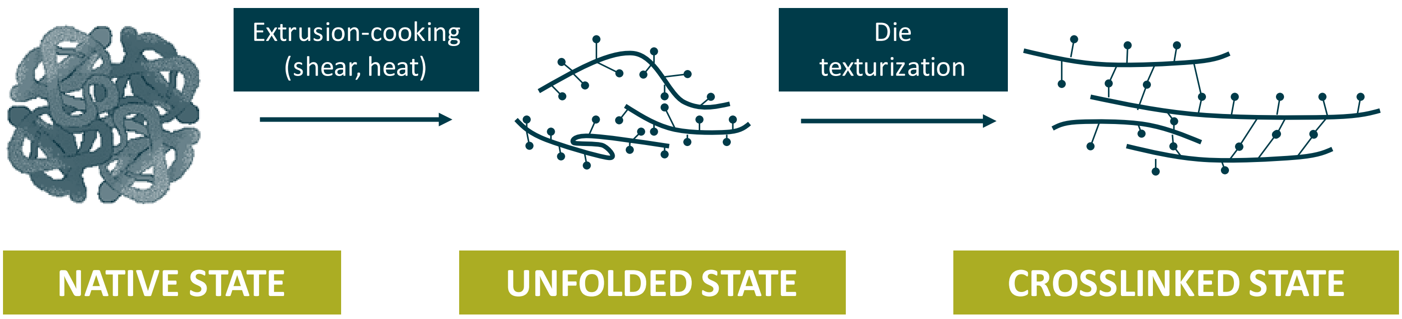
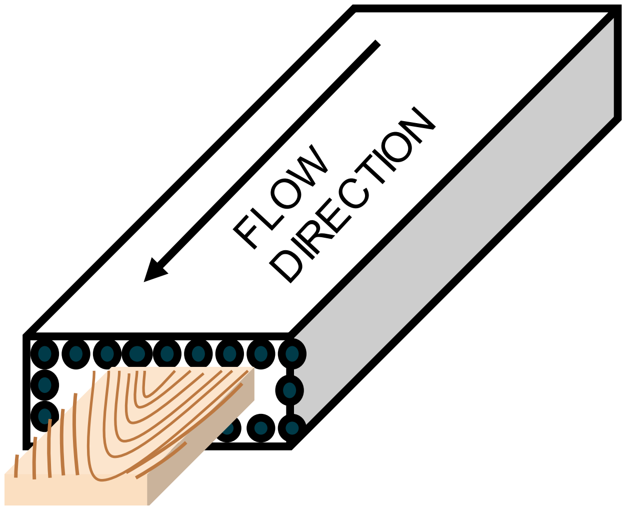


Figure 1 : Mechanism of fiber formation in Protein Fibration Technology

Residence time of the product inside the fibration die, design of the cooling channels of the die, cross-section area and opening dimensions, are also critical parameters that will greatly impact the quality of the fibration.

DIE FIBRATION
Laminar ; Gelling ;
Fiber Formation

Figure 2 :
low-induced die fibration of protein melt



A key point: the texture

The protein fibration technology produces unique intermediate products, with fibrated internal structure similar to meat muscles. The strength of fibration can be adjusted by manipulating operating conditions (particularly mechanical and thermal energies, and moisture content), ingredients and formulation as well as equipment configuration such as the twin screw extruder and the short or long dies.

As an illustration, profile A and profile B in figure 3, shows 2 types of fibration profiles. *Profile A* shows a rough surface, with relatively short and thick, cross- section oriented fibers. While *Profile B* shows a smoother surface, with long and thin laminar-flow oriented fibers.

Each of these products will be dedicated to specific food applications. For instance, profile A might be used as an analog of chicken strips, while profile B might be used as an analog of pulled-pork.

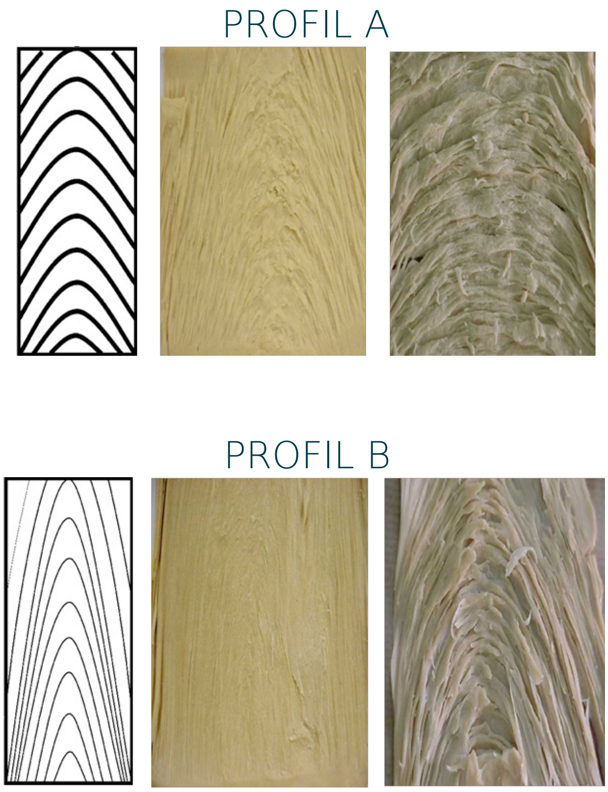


Figure 3 : Fiber formation profile of wet-protein products

Texture profile of meat-like product can be further analyzed using instrumental texture analysis used in traditional meat products. The combination of complementary measurements such as tensile or shear strengths to measure firmness, elasticity, and/or chewiness allows describing the entire scope of texture of the fibrated protein by extrusion.

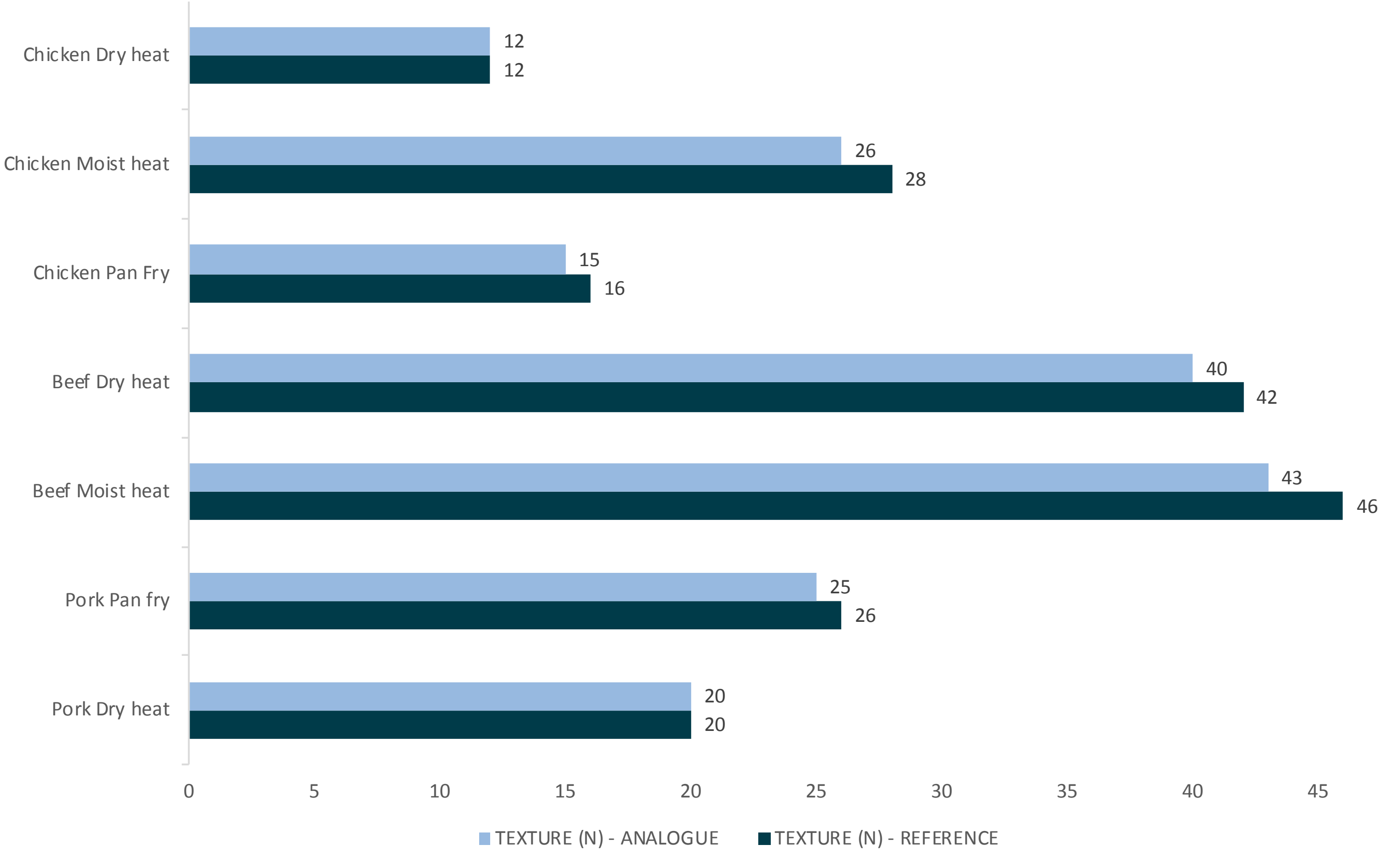


Figure 4 : Comparison of Shear strength using Texture analyzer TMS-PRO across fibrated proteins obtain by extrusion (=Analogue) and meat pieces (=Reference). SFIDC Studies, 2013

CONCLUSION

Twin screw extruders offer a unique innovative and polyvalent method to transform proteinaceous rich materials (plant or animal based) into healthy and well-balanced fibrated protein products with meat-like texture profiles, such as the ones of chicken breast, moist-cooked roast beef, flaky tuna or pork chops.

The product expertise and process know-how are key points to reach the best meat analogues using different protein sources. These new generations of meat analogues show higher conversion efficiency and better environmental impact compared to traditional meat products.
They offer the opportunity to address a new consumer trend called “flexitarism”.

Protein Fibration Technology appears to be one possible key sustainable solution to feed the expected 2 billion worldwide consumers in 2050.

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CLEXTRAL

Clextral, a leader in twin-screw extrusion technology, assists customers in the formulation and production of meat analogues with fibrated structure using its proprietary High Moisture Extrusion Cooking (HMEC) process. Considering that meat-like texture is an essential characteristic of meat replacements, Clextral carried out a qualitative study of the texture of meat analogues produced by the company’s High Moisture Extrusion Cooking (HMEC) process.

As a pioneer in the HMEC process with over 30 years of production expertise, (patent Nr FR 2 827 123 B1) Clextral delivers the equipment and process knowledge to the food industry for producing novel fibrated proteins for meat replacement foods to help feed the world while respecting ethical and environmental considerations.

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