The evolution of a plant-based alternative to meat
From niche markets to widely accepted meat alternatives

Abstract
Plant-based alternatives to meat are a growing market segment. The European LikeMeat project investigated consumers’ motivation for shifting their diets towards meat alternatives and developed a meat alternative product that resembles the fibrous structure, bite and juicy mouth-feel of meat. In a high moisture cooking extrusion process, plant proteins are converted to a base product that has a meat-like structure. Various protein sources and their combinations with further food ingredients were tested to develop this base product, including the creation of flavour components and the addition of aroma ingredients and spices. Furthermore, focus was put on the microbiota. Microbiota were analysed in raw materials as were their inactivation rates during the cooking extrusion process and their potential growth in the refined and packed food product. The LikeMeat base product serves as the base for a wide range of food preparations.

INTRODUCTION
A growing awareness in the population about healthy and sustainable foods has led to a rising interest in plant protein based meat alternatives in many European countries and worldwide. The new consumer group of “flexitarians”, who reduce their meat consumption in their daily diet, is growing rapidly (1). This change in eating pattern requires new products that fulfill consumer demands of healthy and tasty products which both replace the function of meat in a dish and contribute a similar high protein nutritional value. A consortium of academic researchers, along with small and medium sized enterprises, developed new meat alternatives within the European research project “LikeMeat” (11/2010-02/2013). This consortium simultaneously addressed technological development, food safety and consumer aspects. Fibrous meat-like structures were created from plant proteins in an adapted cooking extrusion process and were subsequently processed into tasty food products. Product development was accompanied iteratively by consumer research and extensive microbial analysis to guarantee safe and stable foods.

MEAT ALTERNATIVES
The introduction of meat analogues (also termed meat substitutes, meat surrogates and meat replacement food) in Western markets is a relatively recent development, starting in the early 1960s (2, 3). In contrast, products such as tofu and tempeh have been consumed in Asia for centuries. In addition to these traditional Asian products, the launch of meat analogues started with the production of dry texturised vegetable protein (TVP), which is produced by cooking extrusion of usually defatted soy meal, soy protein concentrate or wheat gluten (4). These products have an elastic and somewhat spongy texture that is utilised favourably in patties, stews and sauces. A further approach to mimic the fibrous and elastic meat structures are fibrous raw materials such as shredded TVP and mycoprotein or milk protein preparations. These raw materials are mixed with water, a binding component and further ingredients, and are then formed and subsequently steamed (5). A broad range of ingredients can be used for these products which, compared to TVP, provide strong differentiation in shapes and flavours as well as products that fulfill attributes such as “vegan”, “organic” and “gluten-free”. 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 (6, 7). The LikeMeat project enhanced our knowledge of suitable raw materials and their characteristics, the influence and interaction of further functional ingredients and flavouring. Adapted and enhanced post extrusion processes, consumer-oriented product development and new smart packaging and preservation solutions opened the market for a new generation of meat alternatives.
ALTERNATIVE PROTEIN SOURCES

Proteins are essential the building blocks of the human body. Proteins of animal origin have a similar amino acid pattern to those in humans and are thus regarded as particularly nutritious. However, meat consumption in industrialised countries (e.g. in Europe 66.2 kg per capita per year in 2010-2012 [8]) exceeds the required amount considerably. This excess meat consumption can be linked to increased risk of cardiovascular disease and gastrointestinal cancer [2, 9]. Furthermore, the associated purines promote arthropathy. The German Nutrition Society (DGE) recommends reducing meat consumption to two or three servings per week (300 – 600 g meat / week) [10].

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. In addition, they allow consideration of further aspects such as free-from gluten, soya, lupine, lactose (milk), or animal derived proteins within the meat analogue category, thus opening up a more differentiated product range for consumers with food-related intolerances and allergies [5]. In order to pursue this approach by carrying out research and development, a total of ten different proteins were analysed for their processing behaviour during the cooking extrusion process and analysed for changes to their taste profile during the hydrothermal treatments undertaken in the LikeMeat project.

CREATING A MEAT-LIKE STRUCTURE

Plant and animal based proteins need to unfold, cross-link and align themselves to form microscopic and macroscopic fibres. The high moisture cooking extrusion process, which is characterised 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 1, 2] [6, 7]. 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. 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 [11-13].

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 [6, 7, 14, 15]. Therefore, the LikeMeat project aimed to expand this knowledge to complex recipes and the influence of various ingredients on the fibre formation. The approach to mix protein ingredients and further components such as starches and fibres was very effective for creating products with a meat-like bite and a juicy mouth-feel as well as for avoiding dominant, disturbing flavours from single ingredients. Further, it allowed the adaption of recipes in a modular way to specific attributes such as vegetarian, vegan and gluten-free. The formed strand serves as a raw material for various post-extrusion processing steps in order to create vegetarian dishes. Equipment that is typically used for meat processing can often be used. The preparation of LikeMeat is easy due to its pre-cooked character and - depending on the product – is similar to the preparation of the corresponding meat product.
FLAVOUR AND TASTE

Besides textural properties, an attractive flavour is a key prerequisite for consumer acceptance and market launch of new meat alternatives (2). These products should be free of off-flavours and the flavour has to meet the expectations of consumers. Many meat alternatives developed in the past, however, lacked aroma and taste quality, which might be one reason for their low market success. Foods can be flavoured either (i) by addition of flavourings or spices or (ii) by odourless and tasteless ingredients which are converted during thermal processing into sensorially active compounds. One natural and well understood process is the Maillard reaction. This reaction occurs during heat treatment of almost every food and bio-converts amino acids and sugars into various odorants, tastants and colorants (16, 17). The LikeMeat project therefore aimed to produce meat analogues with high aroma and taste quality by applying and investigating all possible applications of flavouring. The pure LikeMeat products were not affected by an off-flavour because the protein raw materials were carefully selected and mixed. The meat analogues exhibited only a very weak aroma, they were almost tasteless and the texture properties were close to meat. Depending on the ingredient mixtures, some strands even smelled slightly like chicken meat. The addition of spices, aroma ingredients and/or salt to the mixture prior to extrusion as well as post-extrusion flavouring produced several products with very pleasant aroma and taste. Otherwise, no effect on the fibrous texture was observed. Several meat alternatives with very different meat flavours (e.g. chicken, beef) were obtained showing that it is possible to produce a wide range of products from LikeMeat. Supplementation of flavour precursors such as amino acids and sugars was found to be an alternative way of flavouring but some limitations regarding precursor combinations and amounts were encountered.

MICROBIAL CONTROL AND FOOD SAFETY

Due to their almost neutral pH and high protein and moisture content, meat analogues are highly susceptible to spoilage. Microbiological activity is the major factor as microbial enzymes and metabolites play a secondary role. Data describing the microflora of high-moisture meat analogues produced from plant proteins are not widely available in the scientific literature (18). Therefore, comprehensive microbial analysis of the ingredients and the newly developed products was necessary in order to identify and characterize relevant spoilage and potentially hazardous microorganisms. The low water activity of powdered plant-based proteins does not promote the growth of microorganisms. On the other hand, endospore-forming bacteria [e.g. Bacillus spp. and Clostridium spp.] may potentially survive the extrusion process. Depending on the microbial load of the selected raw materials, relevant concentrations of microorganisms can occur in the pre-mixtures and recipes. This includes the possible presence of pathogenic and toxigenic microbial species. Based on the process temperature and pressure conditions [130 - 180°C, 20 - 50 bar for seconds to minutes] as well as the water content during a typical cooking extrusion process, vegetative microbial cells as well as bacterial endospores are inactivated to a very high extent. All post-process steps are critical regarding product hygiene and the re-contamination risk from the handling and packaging of the meat analogue needs to be minimized. Therefore different post-packaging treatments such as sterilization, pasteurization and freezing of final products should be considered. Within the LikeMeat project the microflora in a broad spectrum of potential protein ingredients and extruded products were characterised with respect to quantitative level and species composition. An established set of ISO based standard methods was used to detect indicator and pathogenic/toxigenic microorganisms. The identification of isolates to the species and strain level was undertaken using a set of molecular methods including 16S rRNA gene sequencing and PCR-based techniques. Furthermore, inoculation trials to demonstrate the inactivation of bacterial endospores during extrusion cooking were performed. The results showed that the microbiological quality of raw ingredients was satisfactory. In detail, the total microbial load of all extruded products was generally low (< 100 CFU/g). Based on culture-based microbial methods, a comparable sporicidal and bactericidal effect was found for both pilot plant-scale and lab-scale extrusion processes. The microbiota of the extruded meat analogue did not contain any Gram-negative bacteria and very low concentrations of Gram-positive bacteria (<< 100 CFU/g). The results of the microbial analysis of the refined products demonstrated the need for post-process heat treatment in order to ensure a shelf-life of several weeks under chilled storage conditions. Alternatively, freezing of the intermediate product would be possible. Pasteurised or sterilised intermediate and final meat analogue products did not show any microbiological activity, even after several weeks of storage at 6°C. The shelf-life of Intermediate LikeMeat products without preservatives and without post-process heat treatment is comparable to fresh meat products.

CONSUMER MOTIVATION

The number of vegetarians and number of consumers who are reducing their meat consumption has been increasing in Europe over recent years (1, 19, 20). Environmental, ethical and health reasons are largely responsible for this – depending on the type of consumer (20). Other reasons are an increased consumer interest in variation and in “new” foods. Thus, in order to achieve a considerable reduction in the consumption of meat one approach is to develop meat analogues that compete directly with meat products. Another approach is to introduce protein products that meet the need for more variation and/or new products. The market for meat analogues is still quite small. For example in the Netherlands, the share of meat substitutes is only about 1% of the total market for meat and meat products, probably due to the fact that present meat analogues do not meet consumer preferences with regard to sensory quality (21-23). In particular the bite, taste and juiciness score low compared to meat. To obtain a larger market share, meat analogues need to compare better to real meat. The approach that looks for new products is particularly fit for a consumer oriented product development (23).

In the LikeMeat project the consumer research addressed meat consumers that already skip meat at least once a week for their main meal. Within this group, four segments were identified with respect to their attitudes and behaviour in relation to protein products. The four main types were classified as respectively health, animal friendly, hedonist and convenience oriented consumers. Based on these consumer groups, conceptual products were generated, recipes were developed and storage, packaging and practical safety issues were taken into account. Using all this input, (near-) final products were
developed. A selection of these products was tested by 88 (mostly Dutch) consumers both at a central location, at their homes and in a restaurant setting in the Restaurant of the Future Wageningen UR. In the latter testing location, the aim was to make the testing situation resemble real life as much as possible. In this real life test in the Restaurant of the Future the objective was to determine what is lacking or what needs to be improved to maximise a positive consumer experience. One aspect to make testing more realistic was repeated consumption of the products by the consumers. Also a free choice of products was part of the testing procedure and product information about the meat alternative was provided to the consumer. Thus, several aspects of realistic consumer behaviour were incorporated into the product testing.

Several food preparations made with the meat alternative such as a burger, a schnitzel (Figure 3), an Italian pasta sauce, a Mexican dish with minced meat analogue (Figure 4), curry flavoured baked strips and unflavoured LikeMeat material that was presented as a “chicken fillet” were tested by the 88 participants in the out-of-home and in-home real life tests. The Mexican dish was the most successful product as rated by the participants, their sensory evaluation, choice behaviour, experiences at home and their remarks. Also the likelihood of eating this LikeMeat dish again and consumer willingness to buy it in a shop was highest. The quantity eaten was highest for the Mexican dish (measured as the percentage of each meal consumed) – probably one of the best indicators of potential success. Additionally, participants judged the Mexican dish as innovative. The Mexican dish seemed to appeal to most consumer segments; hence this product has potential, from both a marketing and business perspective. Next, the schnitzel might have potential to become a successful product as it was also highly rated by the participants in the central location taste test. Some of the products were liked slightly better when information was provided. Probably the information helped consumers to understand product deviations from “normal”, which made them more positive. The findings support our view that the LikeMeat products not necessarily need to be perfect imitations of meat: they can be different, in order to meet the different needs and expectations of the different consumer segments. In all cases, expectations need to be well managed in order to avoid contrast effects in perception (23, 24).

From the findings of the consumer study, workshops with consumers and limited global market analysis that was performed in the LikeMeat project, it was concluded that meat analogues that have success in the market look acceptable, have good sensory properties (especially taste, texture), are convenient and have one or more characteristics that are valued but cannot necessarily be verified by the consumer (e.g. healthiness or environmental friendliness).

A LOOK INTO THE FUTURE

Plant-based food preparations produced, for example, from pulses or grains have always been a major source of protein in the human diet. These raw materials are readily available, can be stored and are affordable. Some of these plant protein preparations such as tofu, tempeh and seitan have very high protein contents and can compete with meat or fish both in their nutritional value and in their function as outstanding food components. Whereas the use of plant-based meat alternatives was motivated for centuries by economic or religious reasons, animal welfare became another key motivation from the 1960s onwards. Recently consumers have started to move towards meat alternatives in order to have a healthy, sustainable and convenient diet and because they want to try new food products. This recent trend is being accompanied and promoted by a growing number of ever more sophisticated new food products from various raw materials. Simultaneously, meat alternatives are becoming widely available in shops and restaurants. Consumer research has indicated that there are opportunities in the rapidly growing market segment of meat alternatives providing one or more of the mentioned target groups are targeted. Selling points for meat alternatives should focus on aspects such as “health”, “convenience”, “sustainable production” and “animal friendly”, and/or be associated with “fun” or a particular cultural style for social events. The LikeMeat material and the variety of products that were developed in the project combine one or more of these “must have” characteristics – either intrinsically and/or in their marketing and communication characteristics.

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REFERENCES AND NOTES


NEW CHOCOLATE AND COCOA INNOVATIONS

Barry Callebaut has presented its extended range of compound coatings and diversely flavoured filings. These specialty offerings are customized solutions for the dairy, confectionery, bakery products as well as ice cream segment. Another technology breakthrough Barry Callebaut will be presenting at the ISM fair in Cologne is its Cocoart™ Collection. The red and purple cocoa powders used as colourings have been obtained by patented cocoa processing (Patent Number WO 2010/093030). This innovation answers to the growing demand by manufacturers of chocolate products for e-number free designs based on cocoa, printed on transfer sheets or rolls for food applications. Revolutionary element in the collection is the world’s first all-natural, e-number free red colour. Therefore the Cocoart Collection™ holds a unique position on the market”.

www.barry-callebaut.com

NEW STUDY ON SUPERBA™ KRILL OIL

Researchers from Aker BioMarine Antarctic, AS have announced the acceptance of a new study on Superba™ Krill oil in the journal Nutrition Research. The study is scheduled for publication in early 2014. The study investigated the effects of Superba™ Krill on blood lipids in subjects with borderline high or high triglyceride levels. In terms of design, a total of 300 volunteers were divided into five groups and supplemented with krill oil at either 0.5, 1, 2 or 4 grams per day or placebo (olive oil). The subjects included in the study had blood triglyceride values between 150 and 499 mg/dL. Blood lipids were measured at baseline, 6 weeks and 12 weeks of treatment. Study coordinator Kjetil Berge, PhD, R&D Director, Aker BioMarine Antarctic commented: “This is exciting because it is the biggest krill study ever conducted in humans to date. We look forward to sharing the full results in the coming weeks”.

www.akerbiomarine.com

HIGH LIPID ALGAL FLOUR DOUBLE WINNER

And the winner is … Roquette’s microalgae High Lipid Algal Flour! This announcement was heard twice during the FIE Innovation Awards ceremony last 19th November in Frankfurt, Messe. Recognised as the most innovative ingredient of the year – taking all categories together, Roquette’s high lipid algal flour had also won the Award for the bakery products category a few minutes earlier.

www.roquette-food.com