

Will vegetarianism, veganism and in vitro meat replace poultry meat?

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Humans are a typical omnivore species. Anyway, meat consumption varies distinctly between cultures and stage of development and/or prosperity level of countries. Highly developed (prosperous) countries are typically eating more meat than low developed ones, but in highly developed countries eating habits (food styles) are changing distinctly since the beginning of the 21st century. People are more and more concerned about the way of animal production and thus change to flexitarian, vegetarian and vegan eating habits. An increasing number of people is also interested in artificial meat (analog meat), insect protein and cultured meat. Especially, cultured meat (clean meat) is believed to have the potential to replace 'normal' meat in the human menu to a distinct degree, despite many unsolved questions. Cultured meat is attractive as it does not require the keeping of farm animals and as the production is believed to have a lower impact on the environment. Therefore, cultured meat may become a serious competitor of 'normal meat', but this may take more time than currently expected.

Keywords: flexitarian; vegetarian; vegan; poultry meat; analog meat; cultured meat; insects

Introduction

Consumption of animal products (mainly meat) was the basis of the development of the cognitive capability of humans. This made the tremendous development of the human species within a few millennia possible. Anyway, the share of meat in human food evolved differently in different regions of the World, mainly due to cultural and/or religious constraints and level of prosperity. In Asia or Africa, e.g., vegetable foods comprise (still) a distinct portion of the daily food intake, traditionally. Besides, in these continents, pork and beef meat consumption is rather low, whereas, poultry meat is accepted as food and consumption is continuously increasing. In general, meat consumption is clearly connected with the status of prosperity, therefore, consumption of animal protein is increasing globally due to the strong development of the economy in some countries during recent years, especially in Asia. Due to the high number of people living in this continent an increase in meat consumption by 1.0 percentage point results in a huge increase in the overall production. Globally, poultry meat production increased by about 20 % within the last 5 years, mainly due to the increase in consumption in Asia, and reached about 120 million tons of slaughter weight in 2017 (Figure 1). But, the highest per capita poultry meat consumption still exists in the 'old' developed (= highly industrialized) countries, like USA (Table 1).

Despite the still high meat consumption in the 'old' developed countries more and more people are changing their eating habits (food styles) there to a more vegetable or even animal products free (vegan) food. This is mainly caused by social changes. On the one hand, due to the distinct reduction of work time during leisure people are more and more dealing with animal welfare and the other hand they are seeking a more healthy nutrition. People missed the development in poultry production towards huge, highly engineered production units and thus are shocked by today's status of 'mass production'. This feeling is intensified by the continuous development of a more emotional relationship towards animals, what is typical for countries with a high living standard. On this background, the eating behavior of people has diversified during recent years. The spread is now between predominantly carnivorous to totally vegan.

Thus, the present overview attempts to summarize the probable reasons behind this development, to describe the present situation and to give an estimation for the future development and its impact on poultry meat production and/or consumption.

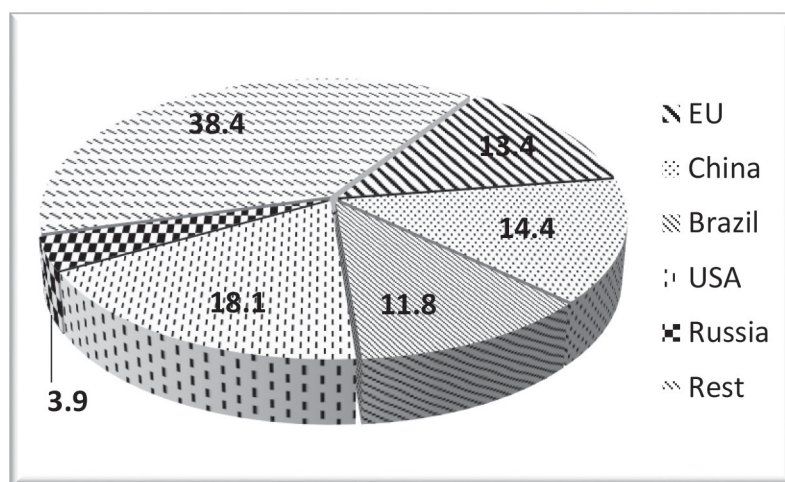


Figure 1. Share (%) of countries in poultry meat production (2017; 118 Mio to slaughter weight; MEG, 2018)

Table 1. Chicken meat consumption in the EU and in selected third party countries (kg/head/year; MEG, 2018)

	2017
EU-28	19.4
Russ. Federation	27.5
Brazil	44.2
USA	48.0
China	8.3
India	3.3

Nutrient requirements of humans

Humans are a typical omnivore species with a focus on highly digestible food as due to the missing of functioning ceca the capability of fiber digestion is rather low. Thus, fiber are mainly fermented by micro-organisms in the rectum resulting in a high gas production and a low utilization of the digestible carbohydrates produced by the bacteria. Anyway, human nutritionists support the increase of the fiber (total dietary fiber, mainly indigestible) content in human diets as it has been proven that low fiber diets increase the risk of suffering from several diseases, like type II diabetes or some type of cancer. On the other hand, humans have high requirements of energy to supply the brain, of essential amino acids (limiting: isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, alanine) and of vitamins, especially of the B complex (e.g. DACH, 2018; NNR, 2014). Normally, those nutrients are highly concentrated in animal products. This is visible by the biological protein value. Meat is assigned values between 70 and 80, whereas, the chicken egg is assigned the value of 100 as it contains these essential amino acids in such high amounts and in an optimal relationship that few eggs can cover the daily requirements of humans. Especially, poultry meat is a good source of essential amino acids and has the advantage that there is no evidence that consumption of poultry meat promotes diseases like colon cancer, as it is reported for red meat (beef, pork). In contrast, in vegetable food some of these amino acids (like methionine) are rarely existing, therefore, reducing the portion of animal products distinctly in the food or, especially, shifting to an animal product free nutrition enlarges the risk of malnutrition, significantly. Meanwhile, it is generally acknowledged by human nutritionists that an annual per capita total meat consumption of about 30 kg would be sufficient to cover human requirements, indicating that the meat consumption in many highly industrialized is too high.

Definitions and reasons for flexitarian, vegetarian and vegan eating habits

Alternative eating habits are flexitarian and vegetarian. Vegetarian comprises vegan, fructarian and 'Rohkostler'. The proportion of these food styles varies between continents and/or countries (Table 2). Anyway, some people still want to eat meat but not produced by farm animals.

Table 2. Human eating habits in 2016 (Statista, 2018)

	Asia	USA/EU
Flexitarian	19	6
Vegetarian	9	2
Vegan	16	6

The share of people with a **flexitarian** eating habit is estimated as 16 and 6 % in Asia and Europe/USA, respectively. These people are conscious about the conventional animal production and refuse to the reached degree of intensification and mechanization (Verain et al., 2015). Today, e.g. broiler houses with the capacity of more than 100,000 birds exist. People feel that this way of production both impacts animal welfare and the environment, negatively. These consumers thus prefer meat from small (smaller) farm enterprises from the region or from organic production. In the same way, they also decided to reduce their meat consumption as they believe that the actual meat consumption is not based on nutritional requirements. In general, they stand by their meat consumption and they are also convinced that this is not in contradiction to any religious, cultural or legal rule. It is generally accepted, that this habit is in accordance with the nutrition physiology of humans and that it may contribute to balance the negative side effects of animal production. The actual share of flexitarian is probably higher than the one given by statistics and will probably increase further in the near future.

The roots of the **vegetarian** habit lay in the 19th century, but vegetarianism is also depending on cultural reasons. In Asia, about 20 % of all people have a vegetarian eating habit, in the industrialized countries this amounts only to about 6 %. The main intention of people with vegetarian eating habit in industrialized countries is the assumed cruelty to keep animals for meat production as they have to be killed (Singer, 1995). Furthermore, they believe that meat consumption favors the intensification of production resulting also in an impairment of the environment. Further arguments against meat consumption are the inefficient way of production (converting already edible protein into animal protein), the destruction of rain forests to enlarge the areas for the production of soybeans as a part of animal feed, and the use of vegetables/cereals as feed stuffs which could be eaten by humans directly. The last argument is not comprehensively valid as the total area of arable land on the World is too limited to produce a sufficient amount of cereals to feed the continuously increasing human population

due to their low nutrient density (protein, amino acids). A big portion of the land area is grassland, which can only be efficiently utilized by ruminants (Von Witzke et al., 2017). So, the competition argument holds only for pigs and poultry. Anyway, vegetarians refuse to eat meat but still consume milk and eggs. By this, they can cover most of their nutrient requirements, but have to take care about essential amino acids, some vitamins, minerals (e.g. Fe, Ca) and trace elements (e.g. J). It is proven that vegetarians suffer less from cardiac infarction, high blood pressure, high blood lipids and cholesterol levels and have a lower BMI. On the other hand, they have a better supply with some minerals (Mg, K), vitamins (folic acid, C, E), fiber and secondary plant ingredients (e.g. flavonoids). The share of vegetarianism increases only slowly in industrialized countries and, this is over-compensated by the clear increase in meat consumption in developing countries. Thus, vegetarianism will probably not have a negative impact on global poultry meat consumption.

The **vegan** eating habit is a special form of vegetarianism. Strictly speaking, veganism is no specific form of eating but a specific way of living (life style). People with vegan eating habit refuse to eat any animal product. In its strictest form, people also try to avoid using any parts or products of animals. Fructarian (only vegetable products, which can be obtained without damaging the plant, like nuts, windfall etc.) and 'Rohkostler' (eating fruits and vegetables only uncooked, <40°C) habit are further forms which are relatively seldom. Vegan eating habit is going back to the book of Peter Singer 'Animal Liberation' (Singer, 1995). Singer argues that there does not exist any moral justification to take into account the pain of any animal. Other justifications are the missing environmental compatibility of any form of animal production, allergies towards animal products (lactose, lysozyme) and increasing antibiotic resistances, to name only some. Most vegan people started as vegetarian. As veganism resigns totally to animal products requirements of nutrients like calcium, iron, essential amino acids and vitamins D and B often cannot be covered by vegetable sources. In general, vegan nutrition requires an even more intensive dealing with nutrition physiology. People with vegan eating habit have to know the nutrient contents of their main food items as comprehensive as possible to combine them in a suitable way to prohibit malnutrition. Anyway, in this group, the proportion of people with signs of malnutrition is highest. But, veganism as a way of living has entered the mainstream within many societies with animal welfare as the main motivation and has the status of a life-style, meanwhile. Especially, younger people are in favor of veganism as they are also open for other life-style products like Apple products, fashion brands etc. They define themselves by attitudes clearly deviating from the actual conventions. This is also reflected by a huge number of books on veganism, cooking shows in television and posts in the internet. This field is firmly in influencers' hands and, thus, will probably widen further in the future. As long as convinced vegans do not face any health problems due to their insufficient nutrition they will continue on their way. It is estimated that only about 2 % of people in Europe and USA are vegan, but this will probably double within the next decade. Anyway, in a global view the impact on overall meat consumption will be limited.

New eating habits

Meanwhile, a new group of consumers approached preferring 'animal' products which have not been produced by farm animals, like **cultured egg proteins (protein food), insect protein, replacement meat and clean meat**.

Protein foods can be used in many ways in human nutrition. On the one hand, they are used for building up muscles and to reduce body weight. This is a billion Euro market. On the other hand, protein products are important for food processing. Currently, mainly extracts from milk (e.g. whey protein) or chicken eggs are utilized (Windhorst, 2018a). Clara Foods (San Francisco, USA) is using genetically modified (GMO) yeast cells, which are suspended in sugar solutions. The cells produce the relevant proteins, which are separated after the cultivation process. There are several advantages associated with these cultured proteins: 1) no keeping of laying hens; 2) freedom of Salmonella or E. coli; 3) no risk of Avian Influenza infections; 4) no risk of antibiotic resistances; 5) claimed less requirement of water and raw materials (=environmentally friendly); 6) possibility to adjust amino acids profiles to customers' demands. The idea of these protein foods is promising, although an economic assessment is still not available and the acceptance by the society due to applying GMO technique is yet not clear. Normally, protein foods do not impair human health as long as the whole nutrition is balanced. Protein foods have the capability to widely replace the use of chicken eggs as sources in processing but will not replace meat products.

In several regions in the World insects are a normal food component, like in Asia, Africa and South America. Currently, more than 2 billion people eat insects. Insects, especially their larvae, have high contents of protein, essential amino acids, vitamin B12 and minerals. Due to the lower maintenance requirements of insects the utilization of nutrients is better than in farm animals. Furthermore, insects can be easily grown on waste (e.g. of kitchens and restaurants), as long as the hygienic conditions can be controlled. For example, it is claimed that growing buffalo worms require 12 times less feed, 10 times less land and 2,000 times less water per 1 kg protein. During the production the carbon dioxide emission is reduced by 100 times. The worms are 100 % edible, the usability is about 94 % (Isaac Nutrition, 2019). Meanwhile, insects as human food are approved within the European Union under considering strict hygienic protocols (Novel Food Regulation (EU) 2015/2283). So far, the use of excreta or food waste as substrate is not allowed, but the latter one is under discussion. As mainly people in industrialized countries are sicken at insects this type of alternative protein food will probably not gain a bigger market share. It will remain in a niche as adventure food. Health hazards may arise by contaminants, allergenic structures and microbial contamination.

Replacement meat or analog meat is not a really new approach. Many attempts have been undertaken to produce 'meat like' products on a solely vegetable basis. This was also the beginning of the vegetarian era. The problem here is that consumers refuse to eat real meat for many reasons, but they demand, nevertheless, the same sensory attributes for the 'artificial' meat products, including sausages. This is also reflected in product names – veggie burger, veggie sausage etc. – a clear contradiction! In many cases lupine or pea protein is used as a basis and sensory attributes are achieved by supplementing herbs and spices (VZHH, 2014). Nevertheless, despite a similar taste to meat burger or sausages the texture is different (Windhorst, 2018b). In addition, a new variation of replacement meat are novel protein foods like soybean meat, quorn, milk schnitzel or insect burger. Anyway, a distinct share of vegetarians and vegans are purchasing these products, but this share will probably increase only slowly. As these products usually comprise only a smaller part of the whole food the risk of malnutrition is not given.

Clean meat, also known as laboratory-cultured meat, cell-cultured meat or in vitro-meat, is a rather new product with a promising future. This approach is named ‘cellular agriculture’, meanwhile (Windhorst, 2019a). The idea started with its realization in 2013 and the procedure could be developed up today in a way that an area-wide production seems to be possible, soon (Windhorst, 2018b; Deutscher Bundestag, 2018; Windhorst, 2019a). To cultivate muscle cells stem cells from calf fetus are collected and transferred to a nutrient solution. The cells are multiplying to a muscle cell layer which is harvested and processed to burger or similar products (Stephens et al., 2018). Probably, the production of a real meat like steak will not be possible. As only few companies are doing research in this field, due to company secret information on the composition of the nutrient solution and the harvesting process of stem cells is scarce. The main advantages of clean meat are named as 1) no killing of animals, 2) less environmental pollution, 3) less use of feed and water, 4) no use of drugs (e.g. antibiotics), 5) fast adaptation to changing consumer demands. But, there are still many open questions (Stephens et al., 2018; Thorrez and Vandenburg, 2019; Windhorst, 2018b). Is it valid to use the term ‘meat’ for this product? Where do the components of nutrient solutions come from? Have stem cells to be genetically modified? Is it ethically justifiable to use a fetus as donor for stem cells? How many fetus are required? Are they still available after reducing the number of animals kept on farms? What happens to the animal keeping farms? How can the shortfall of manure be compensated? How much protein is necessary to produce 1 kg muscle tissue (protein)? How high is the energy usage per kg protein in comparison to farm animals? Where are the needed protein feed stuffs grown? Is clean meat only a product for developed countries? Can clean meat really replace ‘conventional’ meat production with animals? Do consumers accept the deviating sensory attributes? Will the consumer accept the use of stem cells? Despite these open questions, there are several benefits for companies to develop clean meat (Windhorst, 2018b): ethical reasons (no keeping and killing of animals), improvement of image (no cruelty due to killing of animals), enlargement of product portfolio, being a pioneer in this new market, being the first in the market. This is also the reason for huge companies like Tyson Foods or Wiesenhof to invest in this technology. In summary, clean meat is a new approach to produce ‘meat’ in an ethical way.

Table 3. Companies involved in clean meat production in 2018 (Windhorst, 2019a)

Name	Location	Type
Just, Inc.	San Francisco, USA	Chicken
Memphis Meats	Berkeley, USA	Beef, poultry
Supermeat	Tel Aviv, Israel	Chicken
Aleph Farms	Ashdod, Israel	Beef
New Age Meats	San Francisco, USA	Pork
Meatable	Leiden, Netherlands	Beef, pork, chicken
Higher Steaks	London, UK	?
Mosa Meat	Maastricht, Netherlands	Beef

This development is supported by the market as people are more and more refusing to exploit animals for their own benefits. Especially, meat production has to be seen critically due to the necessity to kill the animal before harvesting the meat. The possibility to produce cultured meat has created a new eating habit – neo-omnivorous (Windhorst, 2019b). It is hard to estimate the market potential of this alternative meat product on a reliable basis due to the high number of unanswered questions. Despite the product price will be reasonable until 2020 (currently about 50 €/kg) it will take another 5 to 10 years to extend the production and to develop the market (Stephens et al., 2018). Although it is unlikely that clean meat will replace ‘real’ meat within a short time, in a medium perspective it has the potential to acquire a significant market share. This is mirrored by the increasing number of companies dealing with the production of clean meat (Table 3). In a long-term perspective, replacement of real meat by clean meat in developed countries is imaginable.

Conclusions

Mainly, in the old industrialized countries people are more and more dealing with the way of producing and processing of their food. This holds especially for animal products, i.e. meat. People believe that the way of production is in conflict with animal welfare and causes environmental pollution. Therefore, a significant portion of consumers changes their eating habits towards flexitarian, vegetarian and/or vegan nutrition, despite the higher risk of malnutrition for vegetarian and vegan. This paved also the way for new foods like analog meat and cultured meat. Especially, cultured meat has the potential to capture a significant portion of the ‘meat food’ sector and may become a serious competitor to conventional meat. As these ‘meat’ products replace only the meat in standard nutrition, malnutrition may not occur. The replacement of real meat will not happen on a short-term but probably on a medium term. But, still extended research is needed to assess the environmental safety of the production of clean meat and the potential superiority compared to conventional meat production (Windhorst, 2019c). In the case, clean meat can assert itself in the market a tremendous change in livestock production and in overall agriculture will take place.

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