Analysis on the Meat Consumption, Dietary Transformation and Cultured Meat

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Abstract—This paper makes an analysis on efficiency and cost of conventional and cultured meat production. Topics focus on the demonstration of existing deficiencies of the former and production advantages and potential benefits of the latter. Changes in statistical data, related to researched topics, and comparison of two meat production patterns are used to support the topics. The general conclusion is that cultured meat is the most promising new-era product to solve global environment, hunger and poverty problems.

1. INTRODUCTION

Cultured meat, which means the patties sandwiched in your burgers are completely cultured in labs, instead of extracted from animal bodies. The taste, texture, and nutrients of cultured meat are nearly completely the same as those of conventionally consumed meat. Currently, in many developed countries, such as the United States and European countries, there are lots of emerging cultured meat tech-companies, and the production methods and technology are constantly improved and innovated. This recent upsurge, dietary transformation, could be explained by several reasons. First of all, the dramatically increasing of meat production and consumption has many negative impacts. Moreover, the consumption of cultured meat instead of conventionally defined meat can change in the global environment. Furthermore, vegetarianism and environmentalism will be prevalent. At last, there are huge benefits from the commercialization of cultured meat.

In this paper, these main reasons and phenomena that are related to the upsurge of cultured meat, are going to be further explained with statistical data. Furthermore, analysis about the externalities created by the development and commercialization of cultured meat will be included. In the end, it tries to subjectively predict the future development of cultured meat, combining objective data and facts, to talk about the significance of this research, and to make some instructive suggestions for these conventional or emerging food-tech companies’ development prospect.

2. MEAT CONSUMPTION AND PEOPLE’S PREFERENCE

2.1 Meat consumption

According to a report on meat consumption, published in Science, as a global level, currently, both the average per capita consumption of meat and the total amount of meat consumed are dramatically increasing. Two contributing factors, which can explain the rising consumption, are increasing average individual incomes and higher population growth [1].
Statistical data shows a strong relationship between meat consumption and GDP per capita. As a country’s economy is developing, individual incomes rise so that people choose to consume more meat and other food types [2].

For example, China, a rapidly developing economy, has experienced a huge increase in meat consumption, driven by rising personal incomes and population growth after Deng Xiaoping’s economic policy, reform and opening up in 1980s. A report says that “In the early 1980s, when the population was still under one billion, the average Chinese person ate around 30 pounds of meat per day. Today, with an additional 380 million people, it’s nearly 140 pounds.” [3]. It makes sense that rising individual incomes (GDP per capita) and population growth result in high growth rate in meat consumption, and this conclusion can be easily proved by the economic data of many developing countries in East Asia. However, in many developed countries, such as the United States and some European countries, changes in meat consumption are less obvious, since these countries have already experienced rapid economic transition periods.

Globally, per capita meat consumption has increased by 20 kilograms since 1961, the average person ate 43 kilograms of meat in 2014 [2]. Combining the moderate amount of meat consumption but with rapid growth rate in middle-income countries, and moderate even slow growth rate but with a huge base amount of meat consumption in high-income countries, witnessing red-hot global economic development and overwhelming population growth, we can predict continuing increase in meat consumption in the coming decades.

Thus, how to accommodate huge changes in meat consumption by utilizing the available resources is going to be an important challenge for any countries in the next decades. Feasible solutions are generally classified into two categories: dietary transformation and advances in science and technology. One of the feasible dietary transformation solutions is to find a relatively perfect substitute for conventionally consumed meat. Cultured meat, the product of the new era, emerged as the times require.

In the next part, people’s preferences will be complementarily discussed in order to optimize the explanation for meat consumption, then, the article will focus on the analysis of cultured meat’s economic benefit, environmental contribution, and its externalities.

2.2 People’s preference
There may be some exceptions going against the relationship between income and meat consumption mentioned above.

One exception is that high-income people (such as executives in high-tech companies), intelligent individuals (such as students and professors in universities), and other people from different levels of society, gradually prefer to eat organic food and cultured meat rather than conventional meat, although they are able to purchase the high-quality conventional meat types.

Various reasons make those people go vegan. 2019 Global Vegan Survey, which has 12,814 participants who are vegetarians from 97 different countries, shows that 68.1% of those people who took this survey went vegan for the animals, 17.4% people went vegan for health reasons and 9.7% people did it for environment, 4.8% people chose the option of “Other” for a combination of all or some of the main three reasons and religious motivation [4].

However, compared to most meat eaters, those vegetarians are still in the minority. “The number of U.S. consumers identifying as vegan grew from 1% to 6% between 2014 and 2017, a 600% increase, according to GlobalData.” said Janet Forgieve. “That’s still a pretty small portion of the total, but other data reveal growing interest in plant-based foods by consumers who don’t consider themselves vegetarian or vegan.” [5]
In general, most people are meat eaters, and those people who go vegan are still in the minority but with a noteworthy uptrend. Notwithstanding few vegetarians globally, those people are playing a pivotal role in the development of cultured meat. Biochemical technologies including cell engineering, genetic modification and synthetic biology are the principles behind the cultured meat production, and those people, who are highly educated with the best technology and knowledge, are the main vegetarian population, simultaneously. For whatever reasons that they went vegan, the incentive for vegetarianism provides the biggest motivation promoting the technological research and development of cultured meat. Entrepreneurs and big companies from various industries also pour ceaseless investment into cultured market, such as Bill Gates, Li Ka-shing’s Horizons Ventures, Google Ventures, DFJ, etc.

Figure 1. 2019 Global Vegan Survey.
3. CONVENTIONAL MEAT AND CULTURED MEAT

3.1 The efficiency issues (economic aspect)

To accommodate the huge amount of meat consumption and its rapid growth rate, meat production must keep pace with increased consumption by further exploiting available natural resources.

Statistical data shows the simultaneous growth in meat consumption and production. Globally, meat production has many similarities with the changing trend of meat consumption:

- Most substantial changes in meat production likewise happened in Asia. In 1961, the meat production in Asia only accounts for 12 percent of global production, but in 2014, Asia’s production increased to 40-45 percent of global production, with a small base number but an astonishing growth rate.
- In 1961, the meat production in North America and Europe accounts for 67 percent together, but in 2014, those regions’ production only accounts for 34 percent, with a big base number but a slow growth rate.
- Globally, absolute increases in meat production happened in all regions, whatever developing or developed countries [2].

Furthermore, conventional meat industry’s problem of tremendous inefficiency is exposed: generally, there is a huge inefficiency in utilization of land resources: only 33% of earth’s surface is land, 71% of that land is habitable, and we use nearly 50% of the habitable land for agriculture (livestock, crops). 77% of the agricultural land are used for livestock (meat production), and the left 23% are planted with crops (plant-based food production). However, that 77% land for livestock only provides 33% of global protein supply, by contrast, the left 23% land for crops provides 67% of global protein supply [6]. This discrepancy between the huge production input and output can be further explained by other agricultural academic terms.

According to Our World in Data, feed conversion ratio (FCR), which measured as dry matter feed in kilograms per kilogram of edible weight output, is relatively high, that FCR of beef is 25 kilograms, FCR of lamb/mutton is 15 kilograms, and FCR of pork is 6.4 kilograms. Protein and energy conversion efficiency in meat production is likewise unsustainably high, 96.2% of protein and 98.1% of energy (caloric) in animal feed inputs lost during the beef production; 93.7% of protein and 95.6% of energy (caloric) in animal feed inputs lost during the lamb/mutton production; 91.5% of protein and 91.4% of energy (caloric) in animal feed inputs lost during the pork production [2]. These three kinds of meat, beef, lamb/mutton and pork, that people most frequently eat are in the top three in both FCR ranking and protein/energy inefficiency ranking.

Notwithstanding very little comprehensively estimated industrial data for cultured meat production because of the fact that this product is still in a preliminary stage, we can still make a general comparison...
between conventional and cultured meat production. Cultured meat production is totally different from conventional meat production in production process, technological content, energy conversion ratio, etc.

In conventional meat production, the first half of the stage is that livestock are raised in barns and then on farms, eventually they are slaughtered in slaughterhouses. In the first half of the stage, inputs are land resources (barns, farms, slaughterhouses occupy lots of land wastefully), feed (dry feed, water), employees (feeders, slaughterers, managers). After that, livestock’s meat is processed into a variety of meat products, then, meat products are distributed, retailed, eventually consumed by people.

However, in the first half of the stage of cultured meat production, staff all work in laboratories where space can be used efficiently through placing petri dishes compactly on shelves higher than a human, instead of building a farm on tens of acres of land where the animals can stay comfortably without disturbance. Staff collect living cells, then let cells multiply into meat. In the first half of the stage, inputs are normal-size workplace (laboratories), employees (biochemical workers, managers), biochemical equipment workers can constantly reuse. After that, the left process is the same as conventional meat production.

Compared with conventional meat production, first, cultured meat production will free up much of the agricultural land that had long been inefficiently used, even the laboratories could become very large if commercialization and industrialization of cultured meat are achieved, but it should be much smaller than barns, farms, and slaughterhouses. Second, cultured meat production’s energy/protein conversion efficiency is very high. Most of the energy contained in the inputs are lost when feed is converted into meat products in conventional meat production process, but in cultured meat production, very few animals need to be raised because living cells from those few animals are able to multiply into inexhaustible patties to be ate by the huge global population. Thus, if industrialization of cultured meat is achieved, production cost will plummet, by getting rid of the heavy production machinery input cost, land rental cost, livestock feeding cost.

Besides, it’s worth noting that during the transformation from conventional meat production to new cultured meat production, we can expect more centralized production because the work requirements of cultured meat production are more rigorous than conventional production. For example, workers and managers in laboratories must be more knowledgeable and prudent than feeders and slaughterers in traditional meat industry, and work environment must be more clean, supervisory, and unified. What’s more, biomechanical apparatus is much more expensive and delicate than the apparatus used in traditional meat production, which also certifies the probability of centralized production. Therefore, the GHG emissions caused by supply chain will rise in the future, as a result of the industrialization of cultured meat, but this is not a concern since supply chain’s GHG emissions is a little fraction, compared with livestock’s GHG emissions.

3.2 The environmental and health issues
In the environmental and health aspect, basically, negative impacts of conventional meat production are increase in greenhouse gas (GHG) emissions, loss of biodiversity, and health problems.

Food production accounts for 26% of global GHG emissions, and the left 74% are caused by non-food production work. Cultured meat shows promise to become the pivotal force for the optimization of that 26% GHG emissions [2].

The approximate GHG emissions created by meat production can be calculated according to the production process. Whatever conventional and cultured meat production, GHG emissions created by supply chain, including food processing, transport, packaging, and retail, are unavoidable (as mentioned in 3.1). Therefore, to show the negative impact of conventional production on GHG emissions, calculation should stop at the stage of slaughter (supply chain not considered). On-farm meat production accounts for 31% of food GHG emissions. Land use means destroying and converting forests and grasslands into pastures for raising livestock, and its GHG emissions accounts for 16% of food GHG emissions. Totally, raising livestock can create 52% of food GHG emissions, leaving supply chain GHG emissions out [2].
By contrast, cultured meat production occupies little land with very little livestock, and much of the currently used pastures can be converted into forests and grasslands, which can probably further mitigate the greenhouse effect, due to strengthened plants’ purification effects.

Conventional meat production destroys, cuts apart, degrades wildlife habitats by converting forests and grasslands into pastures, causing forests degradation, land desertification, climate changes. All those abnormal natural changes can seriously reduce biodiversity. Currently, 85% of species such as birds, amphibians and mammals are threatened by habitat destruction [7]. Meat production is one of the main causes of habitat destruction.

Another issue that people are particularly concerned about is health problem. First, in animal husbandry, it’s possible that one particular interspecific disease widely spread among this species, then cause massive food shortages in some regions even all over the world. For example, hog cholera was firstly found in 2018 in Shenyang, China, then, it broke out all over China, causing pork prices to rise to an exaggerated level. As a developing country, pork accounts for nearly 70-80% of Chinese people’s daily diet, which tremendously influences Chinese people’s living standards. Second, illegally raised and sold animals may have some terrible virus that can be transmitted to people. For example, in 2002-2004, SARS broke out in Guangdong province, China, the reason is that lots of people in Guangdong eat Paguma larvatas and bats that carried various virus including SARS. It’s a big pity that SARS caused about 900 people died (death toll given by the Chinese government).

Fortunately, cultured meat production can efficiently solve those public health problems, because interspecific diseases will have no way to spread, cultured meat’s cultivation environment is clean and sanitary.

But it’s worth noting that mass disease events, such as SARS 2002-2004, Wuhan pneumonia 2020, are all caused by virus in some inedible wild animals. Lots of people in Southern China have an abnormally crazy and terrible pursuit of eating wild animals, and they do that not because they are poor, but for some local religious belief and for wild animals’ aphrodisiacal functions. Cultured meat can never solve those problems if government regulations can’t be improved and people’s dietary habits don’t change.

4. CONCLUSIONS
This paper reviews the existing various problems and deficiencies in conventional meat industry with related data provided publicly. Through the comparison between conventional and cultured meat production, we figure out that cultured meat is a more flexible industry, having the attractive economic characteristics of high-tech content, low cost inputs, short production timelines, and low risk. More importantly, cultured meat is the most promising force that can drive a thorough dietary transformation and release those natural problems including increase in GHG emissions, loss of biodiversity, etc.

The biggest opposition pressure on the development of cultured meat may come from the working class. Admittedly, if industrialization and commercialization of cultured meat are achieved, it will have a huge impact on conventional meat industry. Tens of millions of jobs would disappear, traditional food giants will face transformational challenges, and many countries like China, that achieve economic rise by relying on heavy industry and agriculture, will probably be temporarily left behind by the United States in this new market.

For U.S. government and food-tech companies, they should recognize the potential big industry transformation during the development of cultured meat, and relatively big frictional unemployment is inevitable so that they should make appropriate negotiations with the employees in conventional meat industry, divert enough funds from public revenue and companies’ revenue as subsidies for traditional meat production labors, organize vocational training as soon as possible when the technologies of cultured meat are mature, and rationally use the freed land and water resources. However, for developing countries like China, government should relax the restrictions imposed on private enterprises, encourage traditional industry transformation, penalize the monopolies in traditional industries that are reluctant to reform, strengthen the supervision on food safety, and step up rigorous regulations in Chinese stock market, because many Chinese pseudo food-tech companies will probably unhealthily speculate in stock
market and harvest retail investors’ money. Technologically independent and successful Chinese giant companies, such Huawei, Alibaba and Tecent, are all survivors under the brutal competition of free market. Chinese government should realize that blind policy support and economic centralization by converting private enterprises into state-owned enterprises, will not bring a new stimulus for its economic growth in the next decades. Anyway, the establishment of STAR market is seemingly representing Chinese government’s determination to give more development autonomous rights to domestic emerging tech-companies. Unfinished reforms need to be accelerated, for those developed countries, to catch this dietary food transformation that contains lots of potential economic benefits.

This paper still exists some undesirable defects. For example, it lacks sufficient statistical data about cultured meat’s production efficiency, energy conversion ratio, etc., making it hard to make detailed comparison between conventional and cultured meat production process, because cultured meat is a relatively new concept and industrialization is still years away.

Future research direction about cultured meat will focus on the detailed production data of cultured meat and different food-tech companies’ performance in this new market, as well as other influencing factors on the development of cultured meat, such as religious belief, animal conservationists’ ideas.

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