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Once a Hypothesis is Now an Innovation, which can answer many issues –Cultured meat

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ABSTRACT:

The world population, which is currently 8.2 billion (2025), is predicted to exceed 9.7 billion by 2050. The Food and Agriculture Organisation (FAO) predicts a 70% increase in food consumption by 2050, posing a significant problem due to limited resources and arable land. While meat consumption decreases in industrialised nations, global consumption is growing, because people are not willing to decrease their meat consumption or change their daily diet. The only alternative to meet the expectations and also food needs is to increase the production of meat. But there are many environmental and ethical issues which pose a threat to the world, so the only solution is CULTURED MEAT. Production and development of the in **vitro** meat can solve the posing threats. This paper aims to discuss and give a sophisticated idea about cultured meat. Its implications, effects on daily life, advantages, and disadvantages. Time and cost of production, technology needed to develop the vitro meat, and how it affects the trade of India. People's perspectives, beliefs. It is not a small idea or a concept, it's an innovation which still needs many improvements.

Key Words: Cultured meat, in vitro (in glass), Food Technology, Religious and people perspectives, Greenhouse Gas emissions (GHG), Consumer price, Conventional meat.

1. INTRODUCTION:

More than half of the world's population loves meat and includes it, in their daily diet. We already know that People who consume meat are called **non-vegetarians**, whereas people who do not consume meat are called **vegetarians.** The interesting thing is that people who do not consume meat is because of their Caste, Religion, culture and some for their ethical and environmental reasons. People who do eat meat also have a restriction on what type of meat they eat, like:

Hindus consider Cow as a holy being and sacred, so they don't consume Beef.

Islam-Muslims only eat Halal meat, and it is strictly forbidden to eat pork in Islam (why? We will discuss it later)(Izhar Ariff Mohd Kashim et al., 2023)

Judaism- considers the meat of an animal which has a cloven hoof/a Split hoof and an animal which can Cud (which can bring back food from the stomach and chew it again for better digestion of its food), also known as Kosher meat in Judaism. They also avoid pork.

Buddhism (Buddhists avoid all types of meat, especially in Mahayana Buddhism, but some sects permit meat if the animal was not killed specifically for consumption).

Cultured meat/ Clean meat/Vitro meat/cultivated meat/slaughter-free meat/grown meat/Cell-based meat. All are the same, but this meat changes the very definition of meat itself.

Cultured meat is a type of meat that is not entirely meat; it's a meat that can be obtained without harming or slaughtering animals, and it's a meat where we can add more nutrients when producing it. **Vitro (in glass) meat** means meat produced in a glass at a certain environment in labs, it's also known as **clean meat** because of its hygienic production method, no added antibiotics and no slaughter of animals.

Despite all of this, can this meat be edible? Can this meat be competent to satisfy the people of different cultures and religions? Are there any risks involved in the production or consumption of this meat?

There are many unanswered questions related to this.

- The first thing people wanted to know about this is? **How is it prepared**?

In simple terms, it is grown from animal cells. But if we go deep, it starts with:

- **Cell Extraction**: A small sample of animal cells is taken from a live animal, often through a painless biopsy (a medical procedure that removes tissues or cells from the body of a living thing, humans and animals, for examination)
- **Cell Culturing**: The cells are placed in a nutrient-rich medium that encourages them to grow and multiply. (This process provides the cell with the necessary environment, nutrients, gases and everything it needs for survival and growth)
- **Scaffolding and Structuring**: To create the structure of meat (like muscle fibres), cells are grown on a scaffold that mimics the extracellular matrix found in real meat. (This process is also used to grow the necessary fats required for the meat).

- **Harvesting:** Once the tissue has matured, it's harvested and processed into meat products like burgers, nuggets, or even steaks.(Wang et al., 2023)

- The second thing most people wonder about is **Time and production cost.**

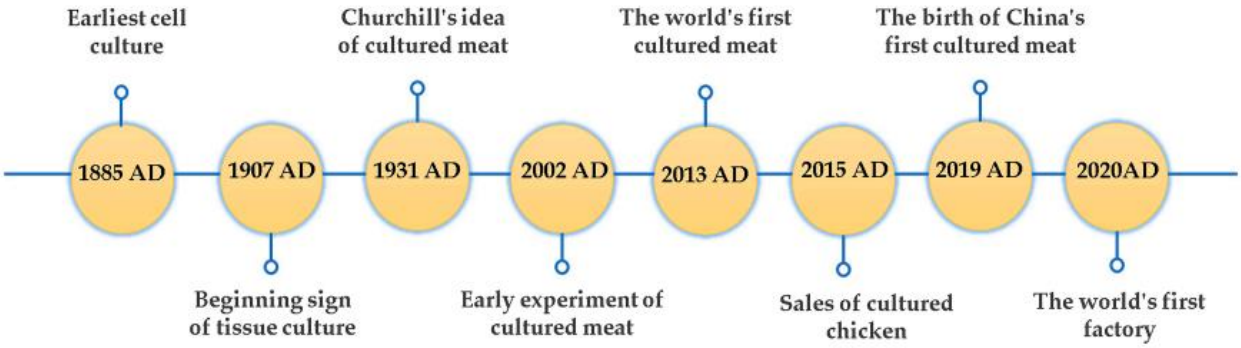
The interesting thing about the vitro meat is, we can obtain any type of meat, whether it is chicken, goat, sheep, Beef, fish, or anything. Cultured meat technology can be applied to **almost any type of animal meat**, as long as scientists can obtain and successfully grow the right kind of cells. Here are some examples of meats that **can (and have been) grown artificially**:

Meat Type	Status	Companies Involved
Beef	Commercial Trials	Mosa Meat, Aleph Farms
Chicken	Approved & sold	GOOD Meat, UPSIDE Foods
Pork	In Development	Mission Barns, Meatable
Duck	Early Development	UPSIDE Foods
Tuna/Salmon	In Development	Finless Foods, Wildtype
Shrimp/Lobster	In Development	Shiok Meats
Lamb	Early Development	Vow, Future Meat

The production time of cultured meat depends on the type of meat being produced. Chicken takes less time compared to beef and pork; the same applies to other meats as well. It also depends upon the type of cells and growth-like muscle takes less time (2 to 3 weeks), whereas certain parts, fibres, and fats of meat take longer (4 to 6 weeks). But it all comes to a point of technology and skilled manpower needed to produce the vitro meat. Better technology, workforce, and good research and development will increase production gradually, based on the market demand for cultured meat. **Example**: Paper was a very valuable product during the 2nd century B.C.E. because during that time, China knew paper making, and the knowledge of making paper was kept a secret by China. It wasn't until the 6th Century B.C. that the technique was brought by a Buddhist monk to Japan, and then it started spreading towards the east and west by travellers, Abbasid caliphates, traders, and colonizers. By the 12th century BCE, paper had spread widely throughout the world, and by the 19th century, paper had become a cheap commodity and was available to everyone because of mass production and improved technological advancement.

By this, we may tell that any commodity which is new to the people will take time to produce and adopt, but over time in the long run it will show the result by demand, supply and price of the commodity. (Choudhury et al., 2020)

Now, coming to the **cost of production**, we have to look back at the time when cultured meat was introduced:



Picture 1: History of the idea and development of cultured meat over the years.

First, cultured meat is nothing but an idea or hypothesis, mostly viewed in Novels as a fictional story of the 1870s. In 1931, **Winston Churchill** (Former statesman and former prime minister of the United Kingdom) said: "We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium. Synthetic food will, of course, also be used in the future".

Then, in the late 1990s, Willem van Eelen[1] was the first applicant to file the first patent for a cultured meat manufacturing method. In 1998, Morris Benjaminson and the National Aeronautics and Space Administration (NASA) made the first attempt to grow goldfish meat within a laboratory as a part of its research into food production for protracted journeys through space. From then on, experiments on cultured/Vitro meat started and attracted many countries. The general public became aware of cultured meat only after a television show in 2013 by Mark Post, a member of a laboratory at Maastricht University in the Netherlands. **Post spent two years and USD 280,000 (some sources say 330,000$) to complete the creation of muscle strip beef hamburgers, which were an edible product.** In London, the cooked cultured meat was tasted by two journalists. The first sale of a cultured meat product took place in December 2020 in a restaurant in Singapore. Today, Good Food Institute and New Harvest, two non-profit organisations, are supporting the R&D of cultured meat.[2][3]

Religious and Cultural perspective of the people:

For many countries, approving the cultural meat is a challenge to begin with, because it may affect the domestic industries, which are mainly dependent on conventional meat (Natural meat/livestock, or we can say traditional type of meat) for their business. As we discussed earlier, religious institutions may find it difficult to adopt because different religions have different practices, **for example, for Hindus** in India, sacrificing animals is a part of the festivals in many places. People of Andhra Pradesh, Karnataka,

[1] Father of the cultured meet- William Frederick van Eelen

[2] Sharma, S., Thind, S. S., & Kaur, A. (2015). In vitro meat production system: why and how?. *Journal of food science and technology*, *52*(12), 7599–7607. https://doi.org/10.1007/s13197-015-1972-3

[3] (Wang et al., 2023)

Tamil Nadu, and Telangana follow these traditions more compared to other states. When it comes to Islamic traditions, there are two types of meat: HALAL (permissible) and HARAM (non-permissible) according to Sharia (Islamic law).

HALAL mean[4]

1. Slaughter must be carried out by a Muslim
2. The animal must be in full health when it is slaughtered
3. Slaughter must occur only through a cut to the carotid artery, jugular vein, or windpipe. This practice renders an animal numb to any further pain or undue suffering.
4. Blood must be fully drained after death. No animal should be stunned to death.
5. Throughout these processes (slaughter, packaging, storage) the animal should not cross paths with the Haram products.

HARAM[5] means: foods that are forbidden in Islamic law.

1. Animals which are not clean and eat dirt, like pigs.
2. Animals which are carnivorous, like eagles, vultures (which are mostly dependent on dead bodies).
3. Any animal that is not slaughtered based on halal tradition.
4. Amphibians (Frogs).
5. Meat that contains blood is also banned in Islamic tradition.

To follow all these things while preparing or producing cultured or Vitro meat is not possible and difficult.

Countries and private companies that invested in Cultured meat are coming up with other means of marketing, like labelling the product with the method of preparation, what substance they used to prepare the cultured meat, how much Quantity they used, and the nutritional levels to increase the public trust on clean meat and to change the opinion of the public on Vitro meat.

- Which countries have approved cultured meat?

Several countries have taken significant steps to approve the production and sale of cultured (lab-grown) meat, driven by motivations such as sustainability, food security, and ethical considerations, and some for technological innovations. (Singapore, U.S, UK, ISRAEL):

Singapore: In December 2020, Singapore became the first country to approve the sale of cultivated meat, granting **Eat Just's chicken nuggets** pre-market approval. Singapore aims to enhance food security and reduce reliance on imports by embracing innovative food technologies.[6]

United States: In June 2023, the U.S. Department of Agriculture (USDA) approved the sale of **cultivated chicken products by UPSIDE Foods and GOOD Meat.** The U.S. seeks to support

[4] (Izhar Ariff Mohd Kashim et al., 2023)
[5] (Izhar Ariff Mohd Kashim et al., 2023)
[6] Green Queen. (2024, February 14). *These 7 governments are funding and supporting cultivated meat.* Green Queen. https://www.greenqueen.com.hk/cultivated-meat-government-support

sustainable food production methods that can meet growing consumer demand while addressing environmental concerns.[7]

Israeli: In 2023, **Israeli company Aleph Farms received preliminary approval to produce and sell cultivated beef steaks**, marking a significant advancement in the country's cellular agriculture sector. Israel invests in food tech innovations to bolster food security and establish itself as a leader in sustainable agriculture.[8]

United Kingdom: In 2023, the UK approved the use of **cultivated chicken in pet food, becoming the first European country to do so**. Human consumption approvals are under review, with products like lab-grown foie gras being considered. Post-Brexit, the UK is leveraging its regulatory autonomy to promote biotech innovations and address ethical concerns related to animal welfare. [9][10]

China: Equally, China's first product occurred on 18 November 2019. Zhou Guanghong, a professor at Nanjing Agricultural University, successfully cultivated the sixth generation of pig muscle stem cells in a nutrient solution over 20 days, resulting in a 5 g meat product. Based on this study, Nanjing Zhouzi Future Food Technology Co. Ltd. (Nanjing, China) established the first domestic production platform for "cultured meat" in the same year. [11]

India: India has also shown great interest in developing Cultured meat, and the Indian government approved the research and development of lab-grown meat. Recently Indian government presented its budget document (2025), their it mentioned about the development of **cold chain infrastructure and food technology,** which in turn relates to the development of cultured meat.

As a developing country, it takes time and capital to develop the new technology required to produce the vitro meat. However, there are several companies like Clear Meat and Bio Kraft Foods. Clear Meat and Bio Kraft Foods are pioneering the use of cultured chicken and ClearX9™ culture media, while Bio Kraft Foods specialises in cultivated chicken and 3D bioprinting. Bio Kraft also organised India's first public tasting session for produced meat in Mumbai.

- **Regulatory boards of other countries, like:**

The European Union's food safety board, **EFSA (European Food Safety Authority),** which looks after the food production of the country, approved the cultured meat with restrictions on it, like a clear production process should be mentioned on the label and for now, it has limited the quantity of meat to be produced. (Bryant, 2020)

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[7] Cultivated X. (n.d.). *Cultivated meat approvals and prohibitions since Singapore's pioneering step in 2020.* https://cultivated-x.com/approvals/cultivated-meat-approvals-prohibitions-since-singapores-pioneering-step-2020

[8] Associated Press. (2023, December 26). *Israeli company gets green light to sell lab-grown beef steak.* https://apnews.com/article/7735ab4ca3cb7df1ccb06c60ba0b926a

[9] The Times. (2024, January 14). *Lab-grown foie gras may be heading to UK dinner tables.* https://www.thetimes.co.uk/article/lab-grown-foie-gras-may-be-heading-to-uk-dinner-tables-frsvklgrh

[10] Financial Times. (2023, September 7). *UK becomes first country to approve cultivated meat for pet food.* https://www.ft.com/content/a9d1390f-93b5-490f-bfd0-af1c73f4d414

[11] https://www.researchgate.net/publication/342318440_Progress_and_Challenges_in_Cultured_Meat

The Food and Drug Administration (FDA) of the United States of America limited production to gauge the public's demand for the new cultured meat. It was overseen by the FDA (preharvest production process and Materials), and the **U. S Department of Agriculture (USDA)** oversees and regulates the post-harvest process, including Monitoring and labelling. (Bryant, 2020)

Food Safety and Security Authority of India (FSSAI) mentioned that as a developing country, India faces the problem of population and, at the same time, food shortage. With this new technology, India can be more nutritious in the diet, and for that cost of production and consumer costs (purchasing cost for the consumer) must be low to make it available to the poor. FSSAI mentioned that India's research and technology department has already started relevant research regarding the topic, and they are confident that they can make it work in the next few years.

Despite all of this, there is **one country that has banned the production and import** of cultured meat: Italy**.** Stating the reason that it will damage the culture and tradition of Italy, and also damage the domestic farmers in their country who are dependent on conventional meat.

- **Advantages and disadvantages of cultured and conventional meat**.

Most of the countries adopting and trying to adopt cultured meat for the same reasons they are:

Food Security: By producing meat without the need for large-scale animal farming, countries can increase their food security and resilience to supply chain shocks.

Ethical Considerations: Cultured meat is a slaughter-free alternative that addresses the animal welfare concerns connected with traditional meat production.

Economic Innovation: Supporting the cultured meat business can put governments on the cutting edge of food technology, attracting investment and creating high-tech jobs.

Sustainable development and environment: According to the Sustainable Development Goals (SDG), Goal 02**: Zero Hunger,** Goal No 11: **Sustainable cities and communities,** Goal No 12: **Responsible consumption and production. The** Sustainable Development Goals were introduced by the United Nations and adopted by all the countries in the U.N. All agreed to achieve the goals by 2030. The SDG aims to end poverty, protect the planet from global warming and greenhouse gases (GHG), and ensure all people around the world enjoy healthy lives and good medical treatment.

When it comes to **Traditional meat or livestock meat**, so far, only Italy has banned the consumption and production of Cultured meat, stating it will damage the cultural heritage of the country. Even though companies and countries are trying to mimic traditional meat, there is no 100% result that it will taste like real meat. Because the culinary world is arguing about the authenticity of meat, stating that Cultured meat is a lab-grown meat which can hardly give the juiciness and tenderness to meat.

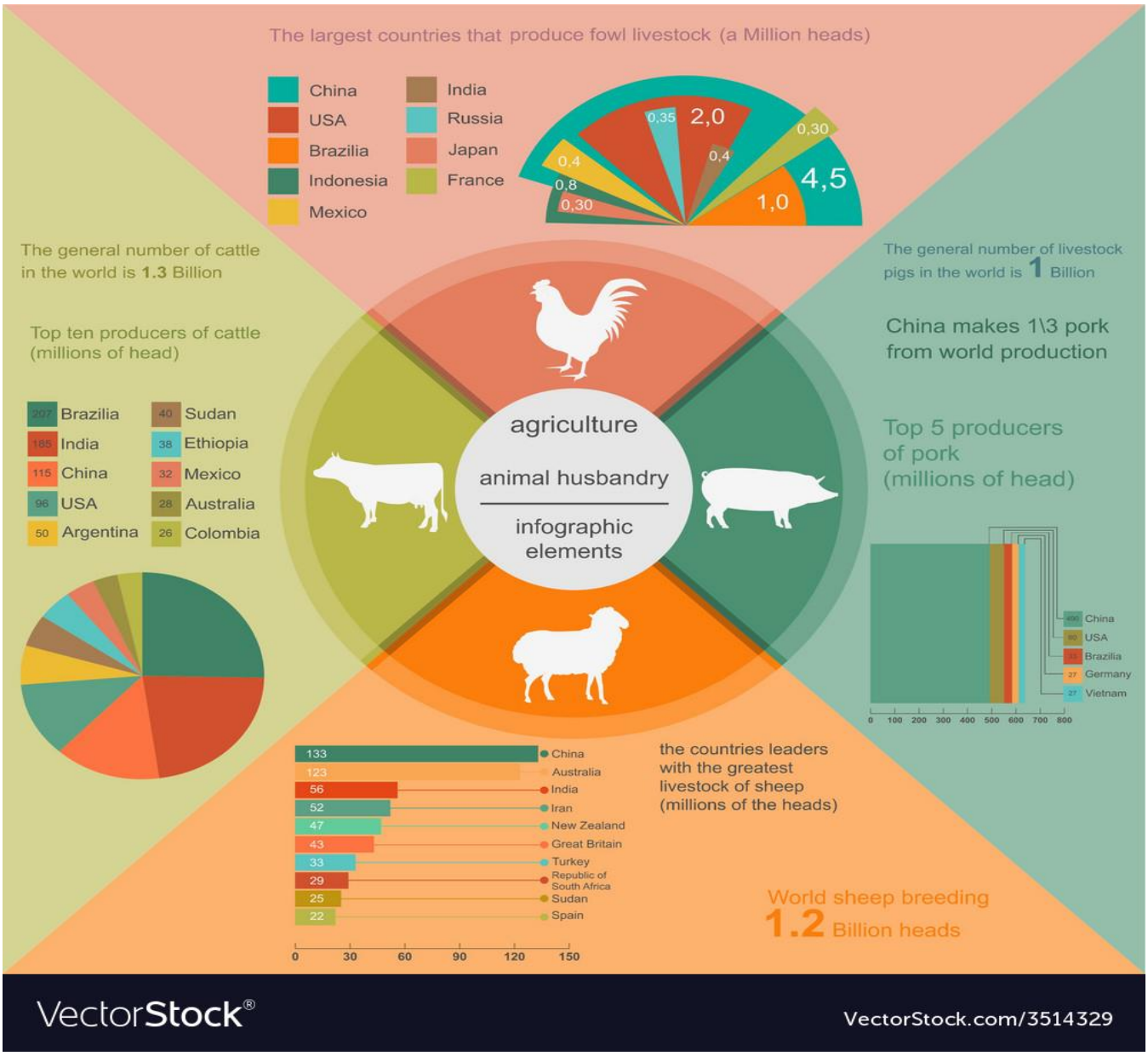
Besides this, man incorporated meat into his diet 2 to 2.5 million years ago. It's not a sudden change; it's a process that happened over the years from the Palaeolithic (Old Stone Age) to the Neolithic Age (New Stone Age) that is present. The domestication of animals began around the Mesolithic age (Middle Stone Age), which is 15000 years ago. The first domesticated animal is the dog, followed by the goat, sheep,

cattle, etc. (THAPAR, 2015). Eating domesticated animals is been a diet for humans for years now, a sudden change in food habits is not going to happen in a night.

If cultured meat becomes popular, the first thing countries will experience is a decline in employment or an increase in unemployment.

According to the Food and Agriculture Organisation (FAO), approximately **1.3 billion people** are involved in livestock value chains worldwide, with over half of them directly dependent on livestock for their livelihoods.

Given that the global workforce is estimated at around 3.5 billion people, this implies that roughly **37%** of the global workforce is engaged in livestock-related activities.**Figure 2:** showing the distribution of animal meat consumed and produced by the largest countries across the globe.



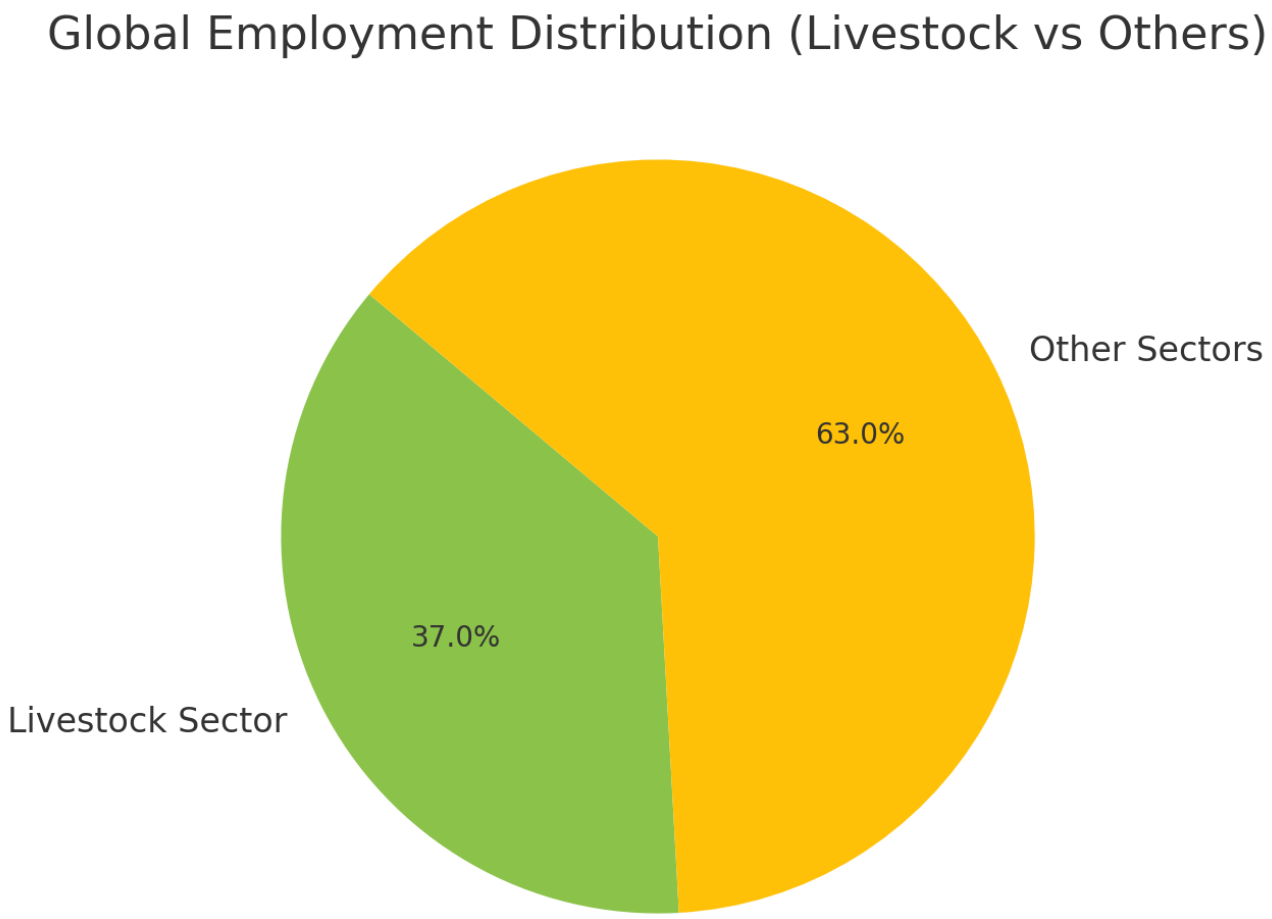


Figure 3 shows employment distribution dependent on the livestock sector(domestication) and other sectors across the globe.

What countries should do:

- Countries should try to diversify the working population into other sectors and divide the skilled and unskilled workers to reduce the sudden decline of the employment rate. So that countries which are more dependent on the domesticated sector can surely minimise the risk of inflation and unemployment.

Disadvantages of culture meat and cultured meat.

As we already know, Cultured meat is quite expensive; according to Mark Post, it took 33,000$ to develop a beef hamburger in 2013. The recent reports show's that from 2013 to 2025, the price of cultured meat has steadily declined with an increase in production and research. Still, it costs 10$ for one hamburger, whereas a normal hamburger is 1$. It is because of the expensive method that is included in the development of technology and research. Scientists and private companies are confident that within the next 10 to 15 years, cultured meat will be available to everyone, regardless of poor or rich. Right now, it is only available as a premium product in some countries like Israel, the U.K., Singapore and the U.S. and many countries yet to possess the technology to develop vitro meat. So, the main disadvantages are the High price, distribution and Technology.

Conventional meat disadvantages:

The United Nations' Food and Agriculture Organisation (FAO) has predicted that the worldwide population could hit 9.7 billion by 2050, along with the global demand, the estimated amount of meat is projected to hit 455 million tons. Nonetheless, conventional livestock farming addressing extensive demands presents challenges concerning environmental resources and public health. and the well-being of animals. Livestock farming occupies 30% of the globe's land resources, uses over 8% of human water use and accounts for as much as 18% of greenhouse gas emissions in CO2 equivalent. Producing just 1 kg of beef necessitates 40 m² of soil, 15 cubic meters of water, and 300 kilograms of CO2 equivalent. Moreover, more than 75% of contagious illnesses in humans originate from animals (zoonotic), and the increasing popularity of vegetarians and Animal rights supporters often aims to decrease the use of livestock products.(Chriki & Hocquette, 2020)

What can cultured meat do?

Cultured meat can significantly benefit the environment by lowering energy consumption (7–45%), greenhouse gas emissions (78–96%), land usage (99%), and water resource demands (82–96%), while also addressing issues associated with conventional farming, like disregarding animal welfare and misuse of antibiotics. Therefore, cultured meat can be promoted as a sustainable meat option that closely mimics actual meat. (Lynch & Pierrehumbert, 2019)

India's position on the present topic:

India is a significant exporter of animal meat, particularly buffalo meat, which is often classified under beef in international trade statistics. In 2023, India's beef exports increased to USD 3.48 billion, up from USD 2.86 billion in 2022. **Buffalo meat** remains India's dominant animal meat export, accounting for over **82%** of the total value. **Poultry products** and **dairy products** contribute significantly, with shares of **4.1%** and **6.0%**, respectively. **Sheep & goat meat** and **natural honey** have smaller shares but are notable contributors to the export portfolio.

Key importers of Indian buffalo meat include:

- **Vietnam**: One of the largest markets for Indian buffalo meat.
- **Malaysia**: A significant importer of Indian meat products.
- **Egypt**: A major destination for Indian buffalo meat exports.
- **Saudi Arabia**: A key market for Indian meat exports.
- **United Arab Emirates**: An important importer of Indian meat products.

These countries are among the top importers of Indian buffalo meat, reflecting the global demand for India's meat exports.

India's meat export industry is supported by major exporters such as Allana sons Private Limited, which has been a leading exporter in the sector.

India's Animal Meat Exports by Type (2023–24)

Meat Type	Export Value (INR Crore)	Export Value (USD Million)	Share of Total Exports
Buffalo Meat	₹31,010.10	$3,740.53	82.2%
Poultry Products	₹1,530.20	$184.58	4.1%
Dairy Products	₹2,260.94	$272.64	6.0%
Sheep & Goat Meat	₹643.55	$77.68	1.7%
Natural Honey	₹1,470.84	$177.52	3.9%
Total	₹37,665.51	$4,543.52	100%

By the above data, we can understand that:

- In the fiscal year 2023–24, India's total meat exports were valued at approximately **$4.54 billion USD** (₹37,665.51 crore).
- India's GDP for the same period was estimated at **USD 3.73 trillion**.
- Meat exports accounted for approximately **0.12%** of India's GDP in 2023–24.
- India's total exports (merchandise and services combined) for 2023–24 stood at **USD 778.21 billion**.
- Thus, meat exports constituted about **0.58%** of the total exports.

Buffalo Meat: Dominates the meat export sector, contributing over **82%** of the total animal product exports. The dominance of buffalo meat in exports underscores India's position as a leading supplier in the global market.

While meat exports are a vital component of India's agricultural trade, their share in the overall GDP and total exports remains relatively small.

Cultured meat: How does it affect India’s trade?

As we discussed earlier, in buffalo meat (beef), India is the leading exporter to Vietnam, Saudi Arabia, Malaysia, Egypt, United Arab Emirates, and not only that, Indian exports also include chicken or poultry. Cultured meat majorly focused on the development of Beef and chicken, because of the growing demand in the international market. Already, the United States, the European Union, Singapore, and Israel have started producing Cultured meat of Beef and Chicken. Domestically, these countries started selling clean meat in premium restaurants for consumption. Many research studies have proven that consuming Cultured meat lowers health risks and also helps in reducing environmental pollution. If the prices have decreased, and production of the meat increases, countries may show interest in exporting the cultured meat. That can reduce the export of Indian conventional meat to the world, especially Beef and Chicken, in future. (According to the report on people's perspective over lab-grown meat, they are

still not fully aware of the benefits and process of vitro meat, so it may take 10 to 15 years to take effect on the Indian meat exports).

When we consider the domestic meat consumption of India, India is the fastest-growing country in terms of population, with 1.46 billion. Meeting the needs of a growing population in a country is difficult:

- As of the most recent data from the National Family Health Survey (NFHS-5, 2019–21), approximately **77% of Indian adults aged 15–49** consume some form of non-vegetarian food, such as meat, fish, or poultry, either daily, weekly, or occasionally. The proportion of non-vegetarian eaters in India has increased over the years. For instance, the share of Indian adults who eat meat rose from 74% in 2006 to 80% in 2021. **Regional Differences**: Non-vegetarian consumption is higher in eastern and southern states, with regions like Lakshadweep reporting up to 98.4% of the population consuming non-vegetarian food.
- Domestically, people of India mostly consume chicken, goat, sheep and fish. Whereas beef and pork are the lowest consumed meats in India because of the religious and cultural traditions.

With its increasing population, India should come up with an alternative solution to meet the demand. (which is cultured meat)

CONCLUSION:

The development of Cultured meat is a challenge to many countries, because developing cutting-edge technology and focusing on research and development requires so much funding and time, which most countries can't afford. But considering the factors that conventional meat is harming the environment and increasing greenhouse gases, which directly affects Global climate change. Not only that, conventional meat production requires natural resources like land and water. There are many organisations and a new culture called Veganism that are protesting against the animal slaughter and consumption of meat, raising many ethical questions. Cultured meat is a promising solution for preparing safer and healthier food products that facilitate sustainable development in the future. Ultimately, research must continue towards green, simple, and sustainable production methods to move commercialisation. As the technology expands and matures, media coverage and businesses should implement more education and popularisation to rapidly integrate into the market. Relevant regulatory and legislative departments should strengthen measures to ensure the safety of cultured meat. Furthermore, it is crucial to enhance public awareness of environmental preservation and sustainability by means of media and other popular scientific promotional channels.

And hence conventional meat is also important, because without the conventional meat, which is original meat, the production of cultured meat is not possible. But to decrease the environmental effects and meet the demand of the people for meat, and to achieve sustainability for the future, cultured meat is important. So much focus on cultured meat will lead to fewer domesticated animals, which in turn may lead to other problems like disruption in traditional livelihood, and religious chaos in countries like India. So, emphasis on cultured meat is important, but still it should be regulated to maintain the balance in nature.

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