A Review of Omnivorous and Plant – Based Diet Health Effects, Environmental Impacts and Alternative Solutions

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Declaration

I hereby certify that the material, which I now submit for assessment on the programme of study leading to the award of M.Sc., is entirely my own work and has not been taken from the work of others save to the extent that such work has been cited and acknowledged within the text of my own work. No portion of work contained in this thesis has been submitted in support of an application for another degree or qualification to this or any other institution.

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Abstract

The aim of this thesis is to evaluate the omnivorous meat - based, and plant – based food options, nutritional compositions, health effects, consumption motivations and mainly the environmental impacts.

The global population is set to reach 9.8 billion by 2050. The growing demand for potable water, nutritious food, fertile lands are inevitable. Parallel to the population growth, the requirement for meat protein source is growing. However, the animal agriculture is known to be one of the biggest causes of the global warming, green – house gas emissions. The excessive meat, particularly red meat consumption is a cause of serious health issues like obesity, cardiovascular disease, type II diabetes, cancer and stroke. The question has been arisen and to be answered. What will nearly 10 billion people eat, how the food will be produced when the only way to mitigate the climate change impacts are to reduce carbon, water and land related emissions and a significant red meat consumption decrease. People used to consume meat for centuries. The liking factor and the belief of healthiness of meat became the main motivations for consuming meat and meat products, while plant - based products are also consumed for the liking factor, but essentially for animal welfare and environmental sustainability. Meat alternatives with a similar nutritional value and satisfying factors like Impossible Burger can offer a more sustainable option to mitigate the rapidly growing climate change caused by green – house gas emissions. A detailed comparison of a regular beef burger and the Impossible Burger showed, that the consumer who chooses the plant – based vegan option, reducing the environmental impact by 87% to 96%.

In conclusion, meat has always been the main source of the food intake and it will always remain as the most desired food to eat, however the rise of the global warming makes the meat consumption re-assessed as proven to be one of the biggest causes of the climate change.

List of Abbreviations

&	Ampersand
approx.	Approximately
BMI	Body Mass Index
CI	Confidence Intervals
CF	Carbon Footprint
CRC	Colorectal Cancer
CVD	Cardiovascular Disease
EF	Ecological Footprint
FAO	Food and Agricultural Organization
FFQ	Food Frequency Questionnaire
FSAI	Food Safety Authority of Ireland
GHG	Green House Gas Emission
GWP	Global Warming Potential
HR	Hazard Ratio
hPDI	Healthy Plant – Based Dietary Index
IARC	International Agency for Research on Cancer
IB	Impossible Burger
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
MAQ	Meat Attachment Questionnaire
MB	Meat - Based
NCD	Non-Communicable Diseases
OD	Omnivorous Diet
PB	Plant - Based
PDCAA	Protein Digestibility-Corrected Amino Acid Score

PDI	Plant - Based Dietary Index
SFA	Saturated Fatty Acids
SR	Strong Roots
SSB	Sugar Sweetened Beverage
uPDI	Unhealthy Plant - Based Dietary Index
USMARC	U.S. Meat Animal Research Centre
VD	Vegan diet
VEG*NS	Group of Vegetarians and Vegans
WF	Water Footprint
WHO	World Health Organization

Table of Contents

Chapter 1 - Introduction

Veganism has become an emerging trend globally due to the consciousness of healthy food and healthy lifestyle. The growing demand and a spreading of plant based (PB) foods generates a more sustainable environment and a positive health effect for humans. Veganism stands up against animal abuse, slaughter and exploitation as a primary meaning. Generally, people who are following a vegan lifestyle are avoiding eating (no meat, dairy, eggs and fish), using (products are not tested on animals) and wearing (leather clothes, fur) anything which came from animals in any forms. It has become an emerging trend across the globe, particularly since studies have showed that animal agriculture, particularly cattle farming and the dairy industry is one of the biggest triggers of green – house gas emissions (GHG) and global warming as well as the detrimental health effects of red meat consumption.

Plant – based vegan foods are made off 100% plant only. These are usually vegetables, legumes, fruits, nuts and seeds.

Originally veganism is movement for animal welfare which fights against animal exploitation, abuse and slaughter. Recently the focus shifted towards a diet trend, human health effects and environmental impacts, rather than animal ethics.

Veganism is a more drastic version of avoiding animal derived food compared to vegetarianism. Vegans also don't wear any leather or fur which would come from an animal. (Tobias-Mamina & Maziriri, 2021).

Based on researches conducted about environmental impacts about different food consumptions, meat turned out to be the highest contributor to environmental impacts compared to fruits and vegetables. The openness towards plant - based diet is growing amongst the younger generation and females. The level of growth of people who recently, in the last few years started to follow a PB diet is immense. A rapid growth occurred in the U.S between 2014 and 2017, the number of vegans grew from 4 million to almost 20 million in those three years. A survey conducted in the U.S revealed, that the 2/3rd of the participants who took part in the survey lowered their meat consumption in the recent years. A significant growth of flexitarianism (occasional animal derived food consumption) was recognized in the UK, resulted in that 21% of the people deemed themselves flexitarian, also a rise within vegetarians and vegans was observed by nearly 1 in 10 reported being either vegetarian or vegan. Recently

in Spain, the number of flexitarians grew by 25% in just few years. The rise of the meat free people was significant in the recent years in other European countries also. A growth from 1% to 7% was noted between 2005 and 2018. Italy reported a nearly 95% growth between 2011 and 2016 for the same. A result of a global study revealed, that 40% of the people who took part of the experiment lowered their meat consumption in the recent years and almost 10% totally stopped animal derived food consumption. The demand for plant – based substitutes which can replace meat is soaring. The PB market value is predicted to double by 2026, from $1.6 B (2019) to $3.5 B. The highest demanded products were mimicked burger patties ($283M), sausages – hot dog ($160 B) and other products ($120 M). On the other hand, the demand for traditional meat products decreased by 5% between 2015 and 2019 as per research. All other PB alternative products like different type of milks, cheeses, yoghurts, other mimicked dairy products have registered a massive increase in demand, while the demand for traditional dairy products are slowly decreasing. The most used and soared plant – based proteins to mimic meat products are soy, peas, wheat, mushrooms, mycoprotein (Alcorta et al., 2021).

Adherence to a vegan - plant based diet, can reduce risk of developing chronic diseases, such as cardiovascular disease, type II diabetes, stroke, obesity, cancer, ischemic heart disease, metabolic syndrome which result in a lesser risk of all - cause mortality. The lower risk of developing such diseases may resulted to positive health effects due to the PB diet, lower blood pressure, lower cholesterol, lower body mass index (BMI), lower blood glucose level, these are generally diagnosed in people following a vegan diet (Lynch et al., 2018).

A research revealed, that shifting from omnivorous diet (OD) to vegan diet could reduce the green – house gas emission by 54 to 87% and reduce the risk of premature mortality caused by non - transmitted diseases by 18-21%. A low intake of wholesome foods, fruits, vegetables, legumes, nuts and a high intake of sodium rich processed food are amongst the top five causes of health issues caused by cardiovascular illnesses, type II diabetes, cancer and stroke. As it's being a worldwide issue, the health authorities all over the world are concerned to deal with this important threating issue. Approximately one fourth of the world population (2 billion people) are suffering from hunger and malnutrition, making it one of the other top priorities beside environmental sustainability and health consciousness. The Eat Lancet group in 2019 conducted a long - term health and diet plan for maintaining the health issues and ecological sustainability long term by stating food as the vehicle for achieving these goals. A reduction of red meat consumption with a lower intake of fish, eggs poultry, dairy products and a higher

intake of plant - based foods were suggested by the FAO (Food and Agriculture Organization) and WHO (World Health Organization) also (Neufingerl & Eilander, 2022).

Due to the rapidly rising population on the Earth (expected to reach 9.8 billion by 2050) and to all activities the mankind has done particularly in the last 100 years, the air, the water and the land got polluted, the biodiversity reduced, deforestation and soil infertility occurred which all led to rising temperatures, to climate change. This warmer air temperature, the global warming is resulted by the increase of green - house gas emissions, reported nearly 30% of GHG is due to food production, where animal farming has the biggest, plant farming has the lowest impact on this GHG rise. The carbon footprint (CF) is associated with the GHG, generated by food cause. It includes carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O). Water footprint (WF) is related to the amount of water used for the food life cycle of production. Nearly 90% of clean water is used for farming, particularly livestock which responsible for 30% of total WF. The size of the land usage is measured by the ecological footprint (EF). Approximately 80% of total lands are used for animal agriculture, for livestock, including lands used for feed production (30%) (FERK et al., 2018).

There has been a systematic review, a life cycle assessment conducted amongst all dietary options to find the answer for which diet has the least impact on the planet. The assessment suggested that vegan diet is the most optimal choice for the environment sustainability (Jakše, 2021).

1.1 The effect of the Covid 19 pandemic

The Covid 19 virus (coronavirus disease) suddenly hit the world in 2020. It is a worldwide epidemic, with a disadvantageous effect on our planet, on our health and on the world economy. As per estimations, about 75% of pathogenic bacteria which can be found in humans are derived from animals in the last 10 years. A serious conversation has emerged about the trading and disallowing this act of wild life animals as a result of the rise of the pandemic which conceivably originated from a bat, via an intermediate host. Other viruses like Ebola, rubella or HIV are also known to be originated from animals, like mammalians, bats, chimpanzee as in some countries as some of these animals are widely hunted and even consumed. Regulating the hunting and trading of these animals are not necessarily the only solution as the rising of deforestation, growth of farm lands and mainly industrial animal agriculture are significantly rising, and contributes to be other major drivers of these communicable dangerous diseases. As

the trend and demand for meat consumption is continuously rising as of the forecasts, expanded risks of upcoming zoonosis are more than likely to rise (Rzymski et al., 2021).

Coronavirus is a highly contagious aggressive virus caused by SARS COV 2, which stands for severe acute respiratory syndrome. This SARS Covid-19 caused a world to go into a world-wide pandemic, which had triggered to take away many human lives. Based on a genomic analysis, SARS COV 2 is associated with bat viruses, hence bats deemed as a potential main cause. The source between the initial cause then the transmit to humans is unidentified, nonetheless the spread between humans is clearly identified. The reason why the determination of primary host is key, is to establish preventative measures against the virus. The initial researches suggested palm civets and racoon dogs to be the original hosts, however further analyses proposed civets to be the secondary reservoir. Subsequently anti SARS COV antibodies had been found in Rhinolophus bats, indicating them as the origin of replications. Snakes have been identified initially as potential key hosts of the virus, but further genomic tests conducted with SARS like bat viruses, aided the statement of bats be the primary reservoirs (Table 1) (Shereen et al., 2020).

Table 1: Comparable biological attribute examination of SARS COV & SARS COV 2 (Shereen et al., 2020).

Features	SARS-CoV	SARS-CoV-2
Emergence date	November 2002	December 2019
Area of emergence	Guangdong, China	Wuhan, China
Date of fully controlled	July 2003	Not controlled yet
Key hosts	Bat, palm civets and Raccon dogs	Bat
Number of countries infected	26	109
Entry receptor in humans	ACE2 receptor	ACE2 receptor
Sign and symptoms	fever, malaise, myalgia, headache, diarrhoea, shivering, cough and shortness of breath	Cough, fever and shortness of breath
Disease caused	SARS, ARDS	SARS, COVID-19
Total infected patients	8098	123882
Total recovered patients	7322	67051
Total died patients	776 (9.6% mortality rate)	4473 (3.61% mortality rate)

The key reservoirs and way of transmissions can be seen in Figure 1, highlighting the key host (circled in red). Solely Alpha and Beta coronaviruses have the capability to contaminate humans. As we can see in the diagram, poisoned animals used as food, fed to humans are one of the key reasons of the virus to be transmitted from infected humans to the health ones. The

dotted black arrow between bats and mice means the likelihood of viral transfer, as well as the solid black pointer which acts for proved transmits (Shereen et al., 2020).

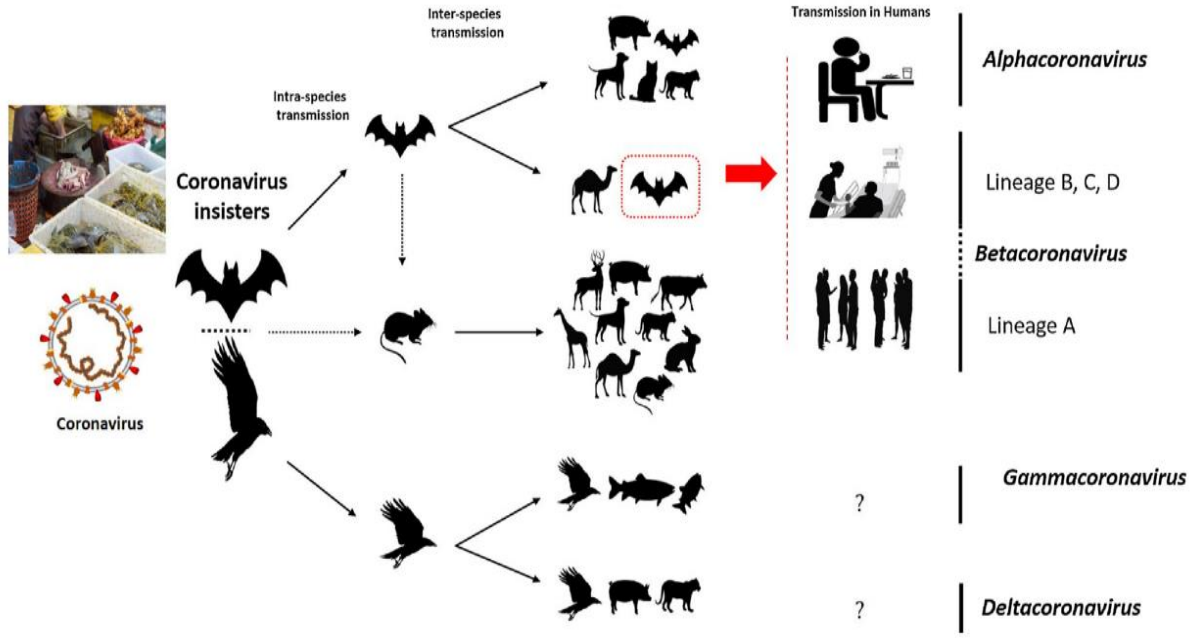


Figure 1: The main pools and transferences of coronaviruses (suspected bat circled in red) (Shereen et al., 2020).

A report about Chinese pigs recently showed, that these types of animals can act as a link to a probable influenza epidemic. Pigs are also exposed to strains of coronaviruses, 6 pathogenic ones are already known. These can easily mutate, like the recent bird swine transformed also to a coronavirus. These interferences are clearly show that not only the wild animals are dangerous to humans but livestock animals can also present serious danger in the future for the human race. A thorough observation can be undertaken to identify new hazardous strains, but it doesn't offer an adequate safety. A detection and outbreak of a new virus can disrupt the security of global food supply. Vaccines might not immediately be available, hence the potential of risk is enormous, as we could have seen it already, when the African swine fever spread out. As a consequence, finding alternative protein sources crucially is vital. It can't be forgotten, that the risk of potential harms is beyond viruses only, animal products contain harmful bacteria, parasites, fungi, prions. Using of veterinary drugs, hormones, antibiotics are associated with industrial animal farming and caring of livestock. Using of antibiotics causes contrariness in the ecosystem. Veterinary residues may remain in the freshwater, potentially causing adverse health effects in humans. Finally, yet importantly, industrial meat production can have a serious adverse effect on the nature, endless deforestation particularly in the

Amazonas which is known to be the lunge of planet Earth, rise of greenhouse gas (GHG) emissions, soil infertility, potable water abolition and disruption in the oceans in the aquatic system (Rzymski et al., 2021).

The Covid 19 pandemic had clearly showed and reminded the world, how dangerous a virus outbreak can be and how dangerous it can be for the humans. Given all the hazard linked to meat consumption & production, an emerging need for alternatives are in great demand, particularly knowing the lack of availability of high-quality meat products, when the interest is continuously soaring. Deliberation of alternative protein source finding is inevitable, whether its plant-based protein, insects sourced or a cultivated meat product, it is urgently needed to be considered. As well as the prevention of future outbreaks is critical, strategies, usual food operations are in need to be re-assessed, in order to risk prevention (Rzymski et al., 2021).

1.1.1 Reduction of meat consumption to be the proposed solution

The demand for meat is still surging an it has been continuously growing in the last 60 years. Developed countries are leading the way, however the growing trend in thriving countries and widely known as a mostly vegetarian country like India is massively expanding. Experts are assuming a duplication in numbers of meat consumption by 2050. Suggestions have been made about meat consumption limitation might provide a solution in order to lower the risk of upcoming pandemics and outbreaks. Population growth, wealth and food choices are driving the growth despite the welcoming diet options like vegetarianism, in forms like lacto, lacto–ovo, pescatarian and mainly veganism, which eliminates all animal derived products and are only dealing with 100% plant-based products. Veganism is not entirely accepted by the society, it often causes confusion and antipathy, mainly due to the dominant carnism. IARC (International Agency for Research on Cancer) labelled red and processed meat as Group 1 carcinogenic to humans & Group 2A possibly carcinogenic to humans also. Several studies have shown the benefits of limiting the intake of animal products. It can help preventing cardiovascular and non-communicable diseases, type 2 diabetes, risk of cancer. Contrarily, a not entirely well-planned vegan diet can bring forth nutrient deficiencies, which can cause health risks. Most of all, the vegan diet is affiliated with a great potential to reduce the environmental impact on land usage, energy, water, and GHG. As reported by the

Intergovernmental Panel on Climate Change (IPCC), PB vegan diet has a leading potential to alleviate the rise of the climate change (Rzymski et al., 2021).

As shown in Table 2, mimicking an original animal product by any plant-based version is quiet challenging. This is mainly by reason of the reluctance of leaving or at least limiting the meat intake by the vast majority of people due to several reasons, such as organoleptic disadvantages, nutrient levels, possible allergenicity, cost, and even non adequacy for pet foods (Rzymski et al., 2021).

Table 2: Main pros and cons of a PB diet contrasted to regular meat production (Rzymski et al., 2021).

Approach	Main Advantages	Main Disadvantages
Plant-based diets	1. Lower epidemiological risks 2. Individual health benefits 3. Lower ecological footprint 4. Ethically superior	1. Low willingness to change the diet 2. Allergenicity in part of the population
Plant-based substitutes		1. Difficulties in mimicking organoleptic properties of meat

As of a summary, the avoidance of future virus outbrakes and pandemics stand in need for multi-level view and process. In spite of the fact that Covid 19 was associated with mainly trading and consumption of wild animals, the livestock industry holds enough risk for future zoonoses. Regulations of the trading of wild animals most likely will not offer a risk-free subsequent outbreak, as well as the control of industrial meat production, hence meat substitutes are wanted pressingly. The success of these alternatives is relaying on government support, technological evolvement, customer satisfaction, but the result will provide a lesser environment impact, energy consumption. Covid 19 with its unwanted impacts on our lives has clearly offered us a moment to overview these ongoing threats and made us aware of the importance of researching and progress in meat alternatives (Rzymski et al., 2021).

Chapter 2 – The Meat Industry, Health Effects, Eating Motivations

2.1. Meat Consumption

The population of planet Earth currently is reaching nearly 8 billion. It is predicted that by 2050, the population will reach to the enormous, 9.7 billion. Planning ahead about how to secure potable water and nutritious food for animals and every human being is beyond challenging. The amount of animal protein is in high demand as being the main source of food, the main challenge is to provide adequate amounts of animal sourced food for the growing population. As being widely and thoroughly evaluated, high meat consumption can rapidly lead to obesity, type 2 diabetes, cardiovascular diseases, colorectal cancer, stroke and to further health issues, as well as it's one of the causing trigger of green-house gas emissions, free land usage, deforestation, and for the last but not least, meat consumption is based on animal slaughter, poultry debeaking, calves separation from their mothers, which leads to an extensive animal welfare issues (Profeta et al., 2021a).

Growing earnings and revenue, rapidly expanding population, social habits and trends are the key factors for excessively growing meat and other animal product demand worldwide. This growing demand trend linearly generates a massive meat consumption, which creates an even bigger problem for the planet, knowing that meat consumption is one of the major drivers of the global warming and ecological deterioration. The freshwaters and soils are depleted and polluted by chemical and medicine residues, like antibiotics and hormones which are cycles back to our food chain. Biodiversity degradation and anthropogenic green-house gas emissions are the negative results of the excessive meat consumption also (Sanchez-Sabate & Sabaté, 2019).

To answer and work on these rapidly growing issues, several studies, researches have been continuously carried out and most importantly, The EAT-Lancet Commission had been established to provide a solution for the future of food (Falchetta et al., 2021).

There are 37 scientist who grouped together from 16 countries with different background to establish a scientific plan by setting goals and targets for achieving healthy and sustainable food for the predicted 10 billion people by 2050, within environmental boundaries (https://eatforum.org/eat-lancet-commission/).

Initially, The Lancet group suggested the animal derived food intake reduction in 2009, as the dietary habits transformation moved towards an unsustainable route particularly in the urban west and resulted in a rapidly increasing GHG emission across the planet. A report found out that a 30% decrease in animal farming and consumption resulted in a 15% increase of mitigating CVD related health issues. A further 10% of CVD related mortality rate can be achieved by lowering red meat consumption and all these actions can bring the GHG emission down by 80% to 90% by 2050. The study also suggests that even a small reduction in meat consumption can deliver great results in dealing with GHG and water footprint (Farchi et al., 2017).

Due to the emerging climate change, the UK Committee had set a 20 percent reduction in meat intake, particularly in beef, lamb and dairy in the UK by 2050. The Committee has stated that meat consumption, especially red and processed and dairy consumption can cause adverse health effects in human body. It's been also stated that greater amount of red and processed meat intake can be directly linked to obesity and development of cancer and cardiovascular diseases along with type II diabetes. The World Health Organization categorized red and processed meat as possibly carcinogenic for humans. The livestock sector has been named as one of the greatest contributors of GHG by generating 15% of the overall GHG. Based on the scientific researches, led the advisory committee of nutrition to set a target of meat reduction from 90 g per day to 70g per day intake for an adult person in the UK. The EAT-Lancet board has advised a minimum of 50% decrease in red meat intake, as well as other crucial dietary habit changes globally, in order to help preserving the environment and increasing human health. Based on a research conducted, an astonishing 89% reduction in beef intake in the UK could keep up with a healthy environmental level (Stewart et al., 2021).

There is an overall global tendency of worldwide population increase which indicates a greater meat demand and consumption. Social habits, traditions and rising income in certain areas of the world are also a great indicator of the increasing meat demand globally. In some of the developed and money-making countries like the UK, meat intake remains high, however the consumption per person tends to decline. As a contrary, in some mid developed countries, particularly in the Asia, the tendency of meat intake is still growing. Animal derived food has always been one of the main sources of nutrition for the humans evolutionarily. Meat and dairy provide essential nutrients for muscle and tissue growth and for an overall body functioning. They've been associated with developing roles for children in both physical and cognitive way (Leroy et al., 2022a).

In this topic, Profeta et al., (2021) stated, that in most of the countries, people are highly connected to meat consumption, their view of meat is something which is essential for their day-to-day diet and life. The solution for these consumers whom are neither open for vegetarianism, flexitarianism nor veganism, a solution could be provided by mixing meat protein with alternative plant-based protein in different ratios in order to achieve a healthier, but mainly more environmentally friendly option. The proportion can vary, but minimum of 20% to 50% is to be alternated with vegan alternative protein.

2.1.1 Trends in Meat Consumption in the UK

There has been a research conducted by Stewart et al., (2021) to evaluate trends in meat consumption in the UK. The research used surveys to monitor these habits amongst the UK population, highlighting their nutritional status, their intake of nutrients and general food intake habits. The quantitative data derived from surveys administered between the years of 2008 to 2019.

The surveys mainly focused on the level of food consumption, particularly red and processed meat intake, fish, poultry, fruits and vegetables, dairy products. Meat products had been summarized by types, end products, etc. Food diaries were collected continuously. Data were collected at individual level from the partakers by self-determining their age, ethnicity, gender, their family income and their diet types. The age was grouped by year of birth, gender was by male or female, ethnicity was determined by being Black, White, Black British, Asian, Asian British and other ethnicity. Household income was grouped based on low to high tertile. The diet type was self-reported as vegan, vegetarian and neither or. A database was obtained to present environmental impact on each meat categories, for poultry, beef, pork and lamb. The data utilized the impact of each meat categories on measures of fresh and stress water usage, GHG emission, land usage, emissions of acids, other harmful emissions. The statistical data gathering was based on a reported daily intake of the consumers, g / day in 4 consecutive days. Vegetarians and vegans were sub grouped. As it shown in Table 3 below, a total of 15.655 people took part of the survey study (Stewart et al., 2021).

Table 3: Socio-demographic attributes and categorization of the year rolling survey (Stewart et al., 2021).

	n (%)
Number of observations	15 655
Gender	
Men	7207 (46·0%)
Women	8448 (54·0%)
Age	
≤10 years	4386 (28·0%)
11–17 years	2922 (18·7%)
18–40 years	3028 (19·3%)
41–59 years	2828 (18·1%)
≥60 years	2491 (15·9%)
Birth-year group	
<1960	3198 (20·4%)
1960–79	3031 (19·4%)
1980–99	3706 (23·7%)
>1999	5720 (36·5%)
Ethnicity	
White	14 026 (89·6%)
Black or Black British	373 (2·4%)
Asian or Asian British	721 (4·6%)
Other	519 (3·3%)
Missing	16 (0·1%)
Equivalised household-income tertiles	
Lowest tertile	4601 (29·4%)
Middle tertile	4407 (28·2%)
Highest tertile	4614 (29·5%)
Missing	2033 (13·0%)
Self-reported diet type	
Vegetarian	334 (2·1%)
Vegan	26 (0·2%)
Neither vegetarian nor vegan	15 294 (97·7%)
Do not know	1 (0·01%)

The report found (Table 4) a 17.4 g decrease in average total intake of total meat between 2008 and 2019 from 103.7 g to 86.3 g. By breaking down this amount, it can be seen that a total red meat grams per day intake dropped from 37.4 g to 23.7 g in the same interval. As well as a reduction in total processed meat consumption, the grams per day intake dropped from 33.8 g to 26.8 g. However, there was an increase in white meat intake in grams per day per capita, from 32.5 g in 2008 to 37.7 g in 2019 and in poultry which increased from 32 g to 35.3 g. Total fish consumption was almost the same between 2008 and 2019, 21.8 g to 21.6 g (Figure 2) (Stewart et al., 2021).

Table 4: Per person intake by meat categories between 2008 and 2019 (Stewart et al., 2021).

	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16	2016–17	2017–18	2018–19	p_{trend}
Total meat												
Grams per day (SE)	103·7 (2·3)	97·4 (3·3)	99·3 (2·56)	94·1 (2·2)	95·4 (2·3)	94·5 (2·3)	99·9 (3·0)	93·6 (2·5)	93·0 (3·1)	87·9 (2·4)	86·3 (2·9)	<0·0001
Percentage of consumers	96%	95%	95%	95%	97%	95%	95%	95%	93%	94%	93%	0·0068
Total red meat												
Grams per day (SE)	37·4 (1·4)	31·4 (1·3)	31·9 (1·4)	30·6 (1·3)	32·1 (1·5)	28·6 (1·4)	30·2 (1·5)	28·2 (1·2)	29·3 (1·7)	25·8 (1·2)	23·7 (1·3)	<0·0001
Percentage of consumers	80%	76%	74%	76%	79%	75%	74%	73%	72%	71%	69%	<0·0001
Total white meat												
Grams per day (SE)	32·5 (1·3)	33·4 (2·5)	35·1 (1·7)	32·8 (1·3)	32·7 (1·2)	33·2 (1·6)	39·6 (1·8)	38·7 (1·7)	38·2 (1·8)	36·2 (1·7)	35·7 (1·9)	0·0027
Percentage of consumers	76%	74%	75%	75%	77%	75%	78%	78%	78%	80%	79%	0·0020
Total processed meat												
Grams per day (SE)	33·8 (1·5)	32·6 (1·6)	32·3 (1·6)	30·7 (1·1)	30·6 (1·2)	32·6 (1·6)	30·1 (1·5)	26·7 (1·2)	25·5 (1·3)	25·9 (1·2)	26·8 (1·6)	<0·0001
Percentage of consumers	81%	80%	74%	79%	80%	79%	78%	74%	73%	76%	74%	0·0003
Total fish												
Grams per day (SE)	21·8 (1·2)	21·8 (1·0)	20·6 (1·0)	21·4 (1·1)	19·4 (1·1)	21·3 (1·4)	21·0 (1·5)	19·6 (1·0)	19·7 (1·0)	21·9 (1·5)	21·6 (1·2)	0·57
Percentage of consumers	63%	64%	61%	64%	61%	59%	63%	62%	62%	61%	63%	0·51
Beef												
Grams per day (SE)	19·0 (0·9)	18·6 (1·0)	18·2 (1·0)	17·0 (1·1)	17·2 (1·4)	14·9 (0·9)	16·8 (1·0)	15·7 (1·0)	16·7 (1·1)	14·5 (0·9)	13·3 (0·9)	<0·0001
Percentage of consumers	62%	62%	59%	60%	59%	59%	58%	57%	57%	57%	53%	0·0004
Lamb												
Grams per day (SE)	7·2 (0·7)	5·1 (0·6)	6·4 (1·0)	4·7 (0·7)	5·8 (0·7)	5·5 (0·7)	5·0 (0·8)	4·3 (0·6)	5·2 (0·8)	4·6 (0·6)	3·3 (0·5)	0·0002
Percentage of consumers	23%	18%	16%	15%	18%	16%	16%	16%	17%	16%	10%	<0·0001
Pork												
Grams per day (SE)	8·4 (0·7)	5·8 (0·6)	5·4 (0·6)	7·6 (0·7)	7·6 (0·8)	6·2 (0·7)	6·9 (0·7)	6·7 (0·7)	6·5 (0·8)	5·6 (0·6)	5·8 (0·6)	0·080
Percentage of consumers	27%	22%	17%	27%	27%	24%	26%	26%	24%	24%	24%	0·48
Other red meat and offal												
Grams per day (SE)	2·8 (0·5)	1·9 (0·3)	2·0 (0·3)	1·2 (0·2)	1·5 (0·2)	2·0 (0·3)	1·4 (0·3)	1·4 (0·2)	1·0 (0·3)	1·1 (0·2)	1·4 (0·3)	0·0002
Percentage of consumers	16%	16%	12%	13%	12%	14%	11%	11%	9%	9%	10%	<0·0001
Poultry												
Grams per day (SE)	32·0 (1·3)	32·8 (2·5)	34·8 (1·7)	32·4 (1·3)	32·1 (1·2)	32·4 (1·6)	38·9 (1·8)	38·3 (1·7)	37·7 (1·9)	35·8 (1·7)	35·3 (1·9)	0·0024
Percentage of consumers	76%	73%	75%	75%	77%	74%	78%	77%	78%	79%	79%	0·0021
Game birds												
Grams per day (SE)	0·6 (0·1)	0·6 (0·1)	0·3 (0·1)	0·4 (0·1)	0·6 (0·2)	0·9 (0·5)	0·7 (0·3)	0·4 (0·1)	0·5 (0·1)	0·4 (0·1)	0·4 (0·1)	0·72
Percentage of consumers	3%	3%	1%	3%	3%	3%	2%	3%	3%	2%	2%	0·90
Processed red meat												
Grams per day (SE)	16·2 (0·8)	17·0 (1·3)	16·2 (0·8)	15·9 (0·7)	15·4 (0·8)	17·4 (1·0)	15·2 (0·8)	14·7 (0·7)	13·9 (0·9)	14·2 (0·8)	13·3 (0·8)	0·0005
Percentage of consumers	70%	70%	66%	70%	68%	70%	65%	63%	63%	66%	62%	0·0002
Burgers												
Grams per day (SE)	2·9 (0·4)	3·2 (0·4)	3·0 (0·4)	2·8 (0·3)	3·2 (0·4)	3·3 (0·4)	3·2 (0·4)	2·1 (0·3)	2·2 (0·3)	2·0 (0·3)	3·1 (0·5)	0·075
Percentage of consumers	14%	13%	12%	12%	14%	13%	14%	10%	10%	11%	12%	0·035

Sausages												
Grams per day (SE)	14·6 (1·0)	12·3 (0·7)	13·1 (1·0)	12·1 (0·8)	12·0 (0·8)	11·9 (0·8)	11·6 (0·9)	9·9 (0·6)	9·4 (0·7)	9·7 (0·7)	10·4 (0·8)	<0·0001
Percentage of consumers	44%	40%	37%	39%	41%	41%	41%	37%	36%	38%	39%	0·060
Processed poultry												
Grams per day (SE)	0	0·1 (0)	0	0	0·1 (0·0)	0	0	0	0	0	0	0·0039
Percentage of consumers	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0·032
White fish												
Grams per day (SE)	8·7 (0·7)	7·9 (0·5)	9·2 (0·6)	7·9 (0·5)	7·8 (0·7)	8·1 (0·9)	7·6 (0·6)	7·2 (0·5)	6·5 (0·5)	7·7 (0·9)	7·9 (0·8)	0·033
Percentage of consumers	35%	33%	35%	33%	31%	31%	32%	32%	31%	29%	31%	0·014
Oily fish												
Grams per day (SE)	7·4 (0·7)	7·8 (0·7)	6·2 (0·7)	7·6 (0·7)	6·8 (0·8)	8·2 (0·9)	8·0 (1·1)	6·9 (0·7)	7·6 (0·6)	8·2 (0·9)	7·1 (0·7)	0·56
Percentage of consumers	24%	24%	23%	24%	25%	24%	27%	27%	27%	28%	27%	0·016
Canned tuna												
Grams per day (SE)	3·3 (0·4)	3·4 (0·3)	3·0 (0·4)	3·4 (0·4)	2·8 (0·3)	2·7 (0·3)	3·3 (0·5)	3·4 (0·3)	3·0 (0·4)	3·9 (0·6)	4·0 (0·5)	0·24
Percentage of consumers	17%	22%	19%	20%	20%	16%	18%	20%	18%	21%	22%	0·38
Shellfish												
Grams per day (SE)	2·4 (0·3)	2·7 (0·4)	2·2 (0·4)	2·6 (0·4)	1·9 (0·3)	2·3 (0·3)	2·1 (0·4)	2·2 (0·3)	2·6 (0·4)	2·1 (0·4)	2·6 (0·3)	0·68
Percentage of consumers	15%	17%	12%	15%	13%	15%	15%	16%	16%	15%	18%	0·22

An overall total and individual meat and processed meat decrease were determined, except burger consumption which slightly increased from 2.9 g to 3.1 g, canned tuna intake which increased from 3.3 g to 4.0g and shellfish consumption which grew from 2.4 g to 2.6 g per person per day between 2008 and 2019 (Table 4) (Stewart et al., 2021).

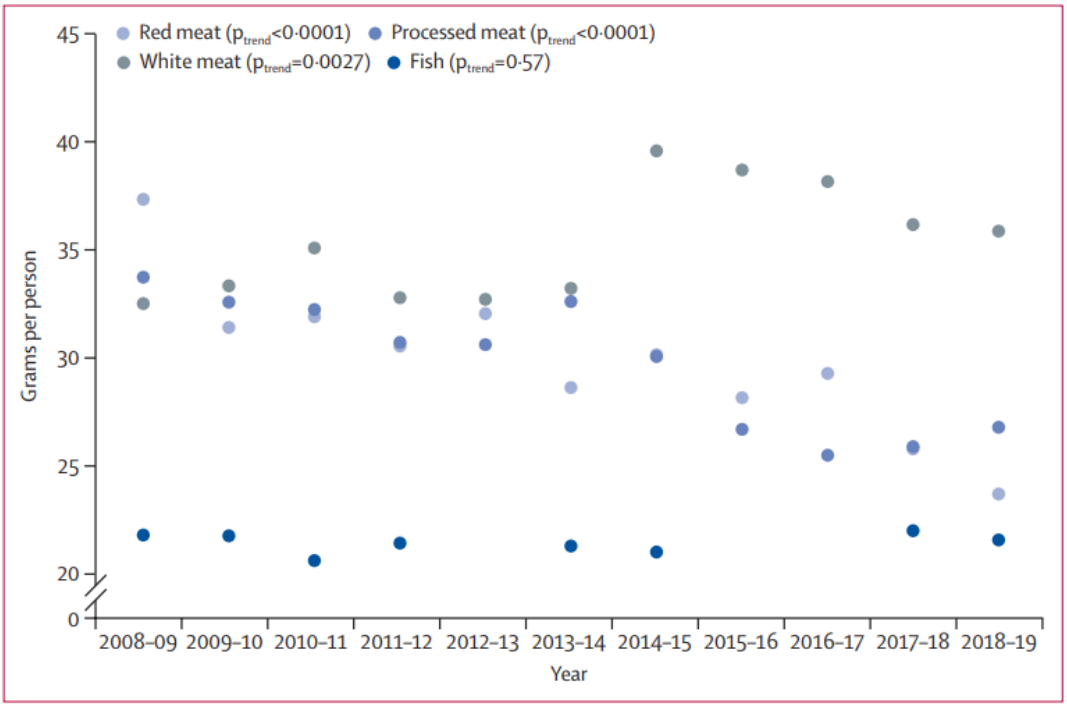


Figure 2: Per person daily intake by meat categories between 2008 and 2019 (Stewart et al., 2021).

By analysing the changes in red meat consumption, beef and lamb achieved a significant decrease by dropping from 19.0 g to 13.3 g and from 7.2 g to 3.3 g (Figure 3). In the processed meat pool, sausages achieved the highest drop from 14.6 g to 10.4 g per person per day between 2008 and 2019 (Table 4) (Stewart et al., 2021).

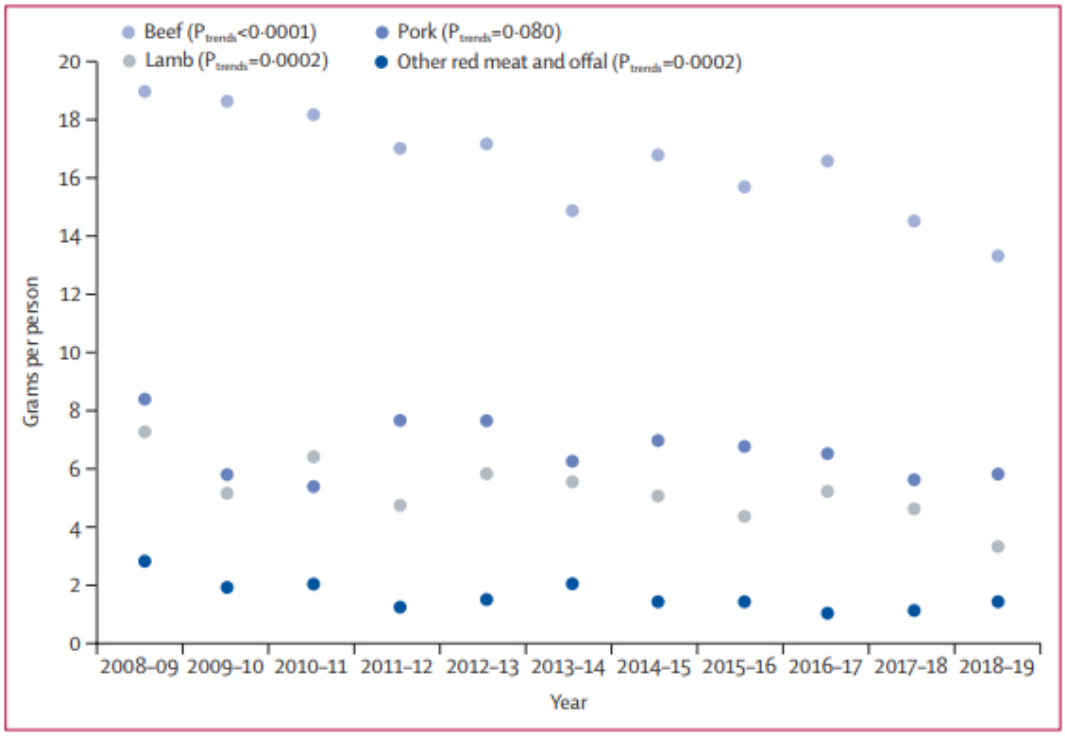


Figure 3: Per person daily intake by red meat categories between 2008 and 2019 (Stewart et al., 2021).

There has been a 70 g per person per day red and processed meat threshold set by the Scientific Advisory Committee on Nutrition UK government department. The ratio of total adult partakers who achieved this threshold has grown from 47% to 66% between 2009 and 2019, inclusive of 74% of women versus 57% of men who achieved the set limitation target (Stewart et al., 2021).

The highest amount of meat intake (food energy percentage) was achieved by the partakers were born between the years of 1980 and 1999. As a contrary, the youngest individuals who were born after 1999 and the oldest aged individuals who were born before 1960 had to lowest meat intake. However, the youngest partakers; meat intake has grown during the period compared to all other sub groups where the overall meat consumption has decreased over the time period (Figure 4, section A) (Stewart et al., 2021).

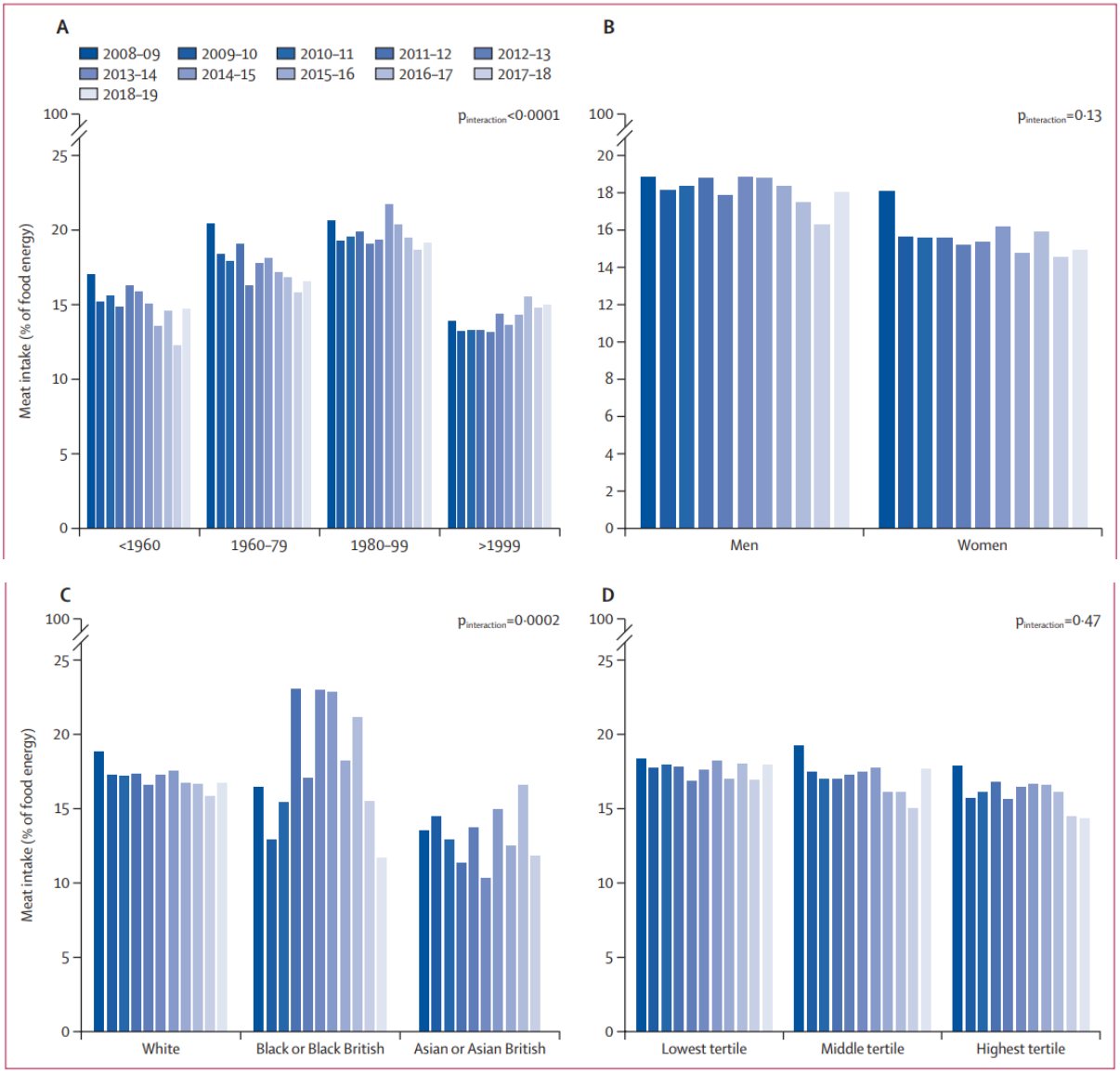


Figure 4: Breakdown of meat consumption by different trends between the consumers (Section A: by year of birth, Section B: by gender, Section C: by ethnicity, Section D: household income) (Stewart et al., 2021).

A slight difference was determined between men and women by meat consumption (food energy percentage) over the time period, but it wasn't significant, and an overall decrease were reported between 2008 and 2019 (Figure 4, section B). The report showed, that Asian and Asian British had the lowest intake of meat compared to the White, Black and Black British group (Figure 4, section C). An overall meat intake drop can be determined within the ethnic groups also, particularly in the White ethnic group. The family income report between the lowest tertile, middle tertile and the highest tertile didn't show a significant alteration (Figure 4, section D) (Stewart et al., 2021).

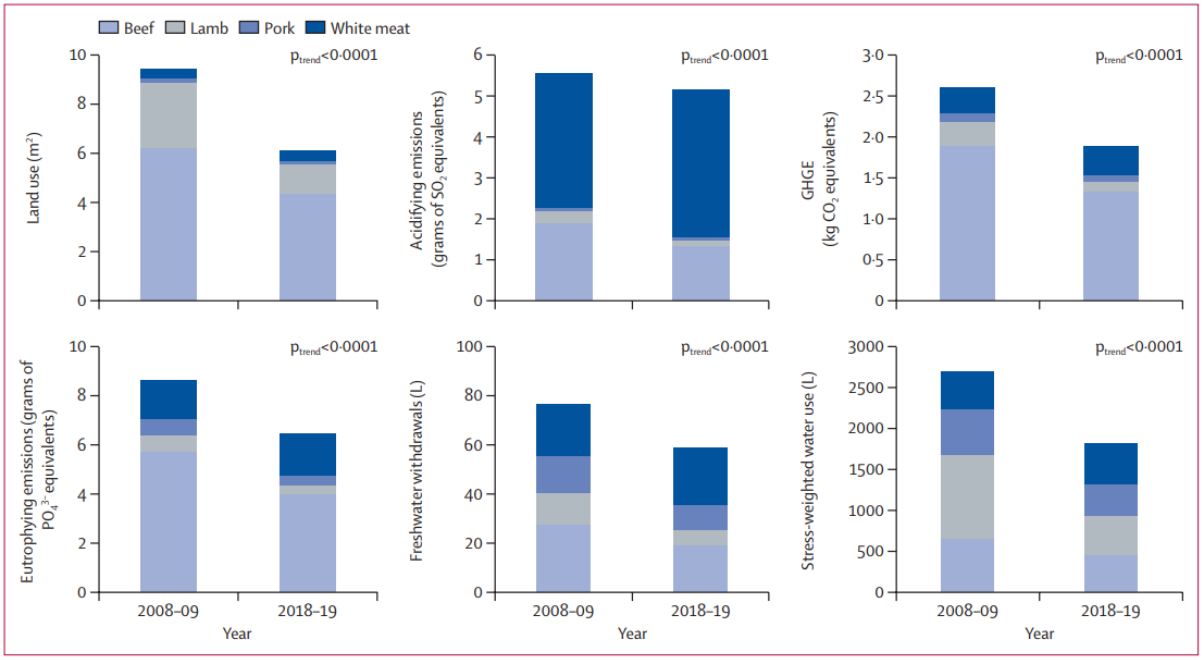


Figure 5: Everyday ecological emissions per head over the six measures by the different meat types (Land use, acidifying emissions, GHGE, Eutrophying emissions, fresh water withdrawals, stress weighted waster use) (Stewart et al., 2021).

Green House Gas emissions, land usage, fresh and stressed water use and withdrawal, acidifying and eutrophying emissions were all expected to be lowered by the overall decrease of meat consumption over the time period of 2008 to 2019. Land use has dropped by 35%, GHGE has achieved a 28% decrease, the acidifying and Eutrophying emissions are lowered by 21% and 25%, the withdrawal of fresh water has been lowered by 23% and the stress weighted water use has been dropped by 33% over the time frame (Figure 5) (Stewart et al., 2021).

In conclusion a significant decrease of meat consumption (17.4 g per head) has been reported by Stewart et al., (2021) over the time period from 2008 to 2019. A 3% point drop of the proportion of the meat in takers has been achieved, as well as a 3% growth amongst the individuals who has been recognized as vegan or vegetarian. The white ethnicity had the highest rate of meat consumption but with an overall decrease overtime, and mostly the partakers who were born in the eighties and nineties and particularly the youngest individuals who were born post 1999 had the highest appetite for meat compared to the older generation. A report suggested that the available meat products for consumption, including raw and processed meat in the UK has grown by 2.9 per day per head, in contrast to the overall meat intake decrease observed over time. The main achievement was observed by the decrease of

all six environmental threat measurements by observing significant lowering. This observation highlights the importance of reducing the meat consumption in order to fight against the global warming. As per the target set by the UK Committee on climate change of achieving a minimum of 20% decrease by 2050 in dairy, lamb and beef consumption seems to be achievable based on the observed 30% decrease in beef and 55% decrease in lamb consumption in the UK between 2008 and 2019. The 20% set target will most likely to be adjusted to a staggering 89% meat intake reduction within planetary boundaries to achieve the desired sustainability targets by 2050. Most importantly by being aware of the meat consumption trends in the UK and in the other parts of the world within the categorized groups of individuals, can help quicken to plan further setting up plans and goals to reduce the overall meat consumption on the planet (Stewart et al., 2021).

2.2. Health Effects of Meat Consumption

There has been an ongoing demand whether animal derived food consumption is healthy and sustainable or unhealthy and non-sustainable based on that battleground which had been generated ideologically on this topic in the last decades. During the evolution of the humans, animal derived foods had always been the main adequate source for nutrition, however nowadays these foods deemed as unhealthy and non-sustainable especially in the western world. In spite of detrimental claims, the nutrient content of meat is essential for the human body as they contain a wide range of nutrients. Excessive amount of red meat consumption plays a role in developing health concerns, such as cardiovascular disease especially in the urban West, however there is an uncertainty among other cultures where the diet contains more wholesome types of food. Universal worry about the environmental impacts is the main threating incident asides from health concerns (Leroy et al., 2022b).

2.2.1. Cancer

A development of a potential colorectal cancer (CRC) in humans has been associated with red meat consumption which continuously generates an ongoing debate about the association between the two factors (Alexander et al., 2015).

During a lifetime, cancer develops 1 in 4 women and 1 in 3 men, which makes a serious health concern. CRC has earned its second position in the most usual cancer type ranking. It is the second behind breast cancer for women, and second behind lung cancer for men. CRC is responsible for 10% of overall deaths caused by cancer. High cholesterol food intake, processed and red meat consumption and excessive amount of alcohol are the leading causes along smoking, physical inactivity and poor diet. A higher pulses intake, minimum three times a week, a higher B6 and folic acid intake, can reduce the development of colon cancer risk by 33% and by adding brown rice to the diet this number can go up to 40%. Legumes, nuts, cooked vegetables can help reducing a risk of colorectal polyps, and large amount of calcium eating can fight against the development of rectum tumours. Further researches and attention are needed as CRC causes a serious health issue with a high occurrence and mortality rate among the diagnosed patients. An overall radical lifestyle change included a lesser meat consumption and greater plant-based food intake and a higher physical activity are needed to prevent the occurrence of CRC with an ongoing screening for early detection (Lopez Pedro J. Tarraga et al., 2017).

Either CRC is associated with red meat consumption or not, due to lack of data sets, in depths analysis and independent studies, one sided result will unlikely be available without being contested from either part.

2.2.1.1 World Health Organization Statement of Carcinogenicity of Red and Processed Meat

The World Health Organization's IARC (International Agency for Research on Cancer) conducted a report in 2015 with a help of 22 researches from 10 different countries in France. The report examined the linkage between red and processed meat and their carcinogenic properties to humans. The report announced, that processed meat consumption is cancerogenic to humans (Group 1), and red meat is also probably cancer causing (Group 2A) to humans (https://www.hsph.harvard.edu/nutritionsource/2015/11/03/report-says-eating-processed-meat-is-carcinogenic-understanding-the-findings/).

According to the FSAI (Food Safety Authority of Ireland) website about the report, red meat is classified as meat from mammalian muscles such as beef, veal, horse, goat, lamb, mutton pork but exclusive of poultry and fish. Processed meat is classified as a meat product which is

treated by salting, fermentation, curing, smoking for the reason of flavour enhancing or preservation. These meat products can be like sausages, ham, salami, etc. The classification of carcinogen by IARC is grouped into 5 categories (Table 5) (https://www.fsai.ie/content.aspx?id=14285).

Red meat is famous for its high protein value, along with essential micronutrient values such as Vitamin B, zinc and iron. The consumption percentage of the red meat varies within countries, but it can measure between 5% to 100%. The average meat consumption of a person per day is in about 50 to 100g. The report was based on an evaluation of eight hundred studies from different countries, continents and ethnic groups, which examined the linkage between cancer development in humans and meat consumption. As a result of the assessment of the studies, colorectal cancer was the biggest concern, followed by prostate and pancreas cancer possibility. However, several studies showed no clear evidence between red and processed meat intake and cancer development (WHO, 2015).

In conclusion, the IARC report categorized red and processed meat as carcinogenic based on the analysis of the 800 studies, however there were conflicting and lacking data in several reports to clearly corroborate the possible linkage. Regardless of the result, FSAI is not recommending the avoidance of poultry and fish consumption as there was no evidence found in these meats, and also no recommendation of a complete avoidance of red meat consumption due to their beneficial values, however limiting the intake can support a healthy lifestyle (https://www.fsai.ie/content.aspx?id=14285).

Table 5: IARC grouping of carcinogens into 5 categories
(https://www.fsai.ie/content.aspx?id=14285).

Group 1	Carcinogenic to humans
Group 2A	Probably carcinogenic to humans
Group 2B	Possibly carcinogenic to humans
Group 3	Not classifiable as to its carcinogenicity to human
Group 4	Probably not carcinogenic to humans

2.2.2 Cardiovascular Disease

Meat offers a variety of a high condition protein globally for the population for centuries. It also provides a full list of essential micronutrients including vitamin D & B12, zinc, selenium, iron, which are essential for the healthy functioning of the human body. However, enormous amount of meat intake is regularly connected to energy and fat over intake which resulting overweight and obesity in most of the cases which leads to an increased risk of non-communicable diseases (NCD) like, cardiovascular disease (CVD), higher risk of chronic diseases, type 2 diabetes and cancer. The acceleration of CVD represents an increased mortality rate both in developed and third world countries. The leading drivers of these chronic diseases often lead to poorly implemented nutrition and dietary habits. Meat has been one of the key food elements for humans for centuries, and the demand for meat has been continuously increasing worldwide, particularly of red meats (lamb, pork, beef) and meats which are processed due to smoking, curing, salting, fermentation or by any other technic which makes the meat tastier by enhancing its flavour. White meats are usually derived from chicken, turkey or fish. There is a potential difference between processed meats industrially manufactured or home-made (Kopčeková et al., 2020).

A considerable amount of assumption has been composed about the connection between red meat but mainly processed meat consumption and CVD. The increased nitrate and sodium content possibly derives from the added salt and preservatives to make the product more lasting. This can lead up to a 50% higher nitrate amount per g and 400% sodium growth per g in processed meats. A higher amount of cholesterol and saturated fatty acids (SFA) in these products have also been addressed in relation to the risk of cardiovascular issues development (Kopčeková et al., 2020).

The brake down of the mortality rates in Europe suggests that 43% of men and 55% of women passed away caused by CVD and approximately 30% were under the age of 65 years. Atherosclerosis deemed to be the main cause of CVD mortality (Kopčeková et al., 2020).

Red meat consumption in the United States of America and in Australia is one of the highest, particularly fresh lean meat and ¼ of the consumption is mainly processed meat. There have been more than several researches conducted over the years about the relationship between red and processed meat consumption and the high risk of cardiovascular diseases and mortality caused by the development of cancer due to a medium to high intake of red and processed meat.

Several studies from the U.S. and Europe suggests that there is a positive correlation between CVD and all - cause mortality and red and processed meat consumption. The rate in these studies for red meat varies between 14% to 50%, and the rate for processed meat varies between 9% to 72%. As a contrary, another study suggested that people on vegetarian diet had 12% lower all-cause mortality in contrast to people on omnivorous diet. This is mainly due to a lesser animal derived food product input and a greater consumption of wholesome food, fruits and vegetables (Alshahrani et al., 2019).

2.2.2.1 The Association of Low Meat Intake with CVD and Mortality

There has been a cohort study conducted with 72.249 participants from Canada and the U.S. with mostly 65% of women and 35% of men. The partakers were required to answer a measurable food frequency questionnaire (FFQ) with over two hundred food items for the assessment. The main aim of this study was to review a low (approx. 49g per day) and zero (0g) per day intake of red and processed meat consumption and all-cause, cancer mortality and cardiovascular disease. The intake was measured in grams (g) per day, then red meat and processed meat intake was also combined as an additional variable. The participant cohort was further broken down as per age, gender, race, education, status of vegetarianism, smoking status (Alshaani et al., 2019).

Throughout the assessment, 7961 people passed away, 2598 deaths were caused by cardiovascular disease and 1873 were caused by cancer based on the nearly 12 years follow-up report. As per the statistics of these death, younger people were associated with the highest consumption of red and processed meat, smoking and drinking habits and higher body mass index (BMI). The report has shown concerns about dietary properties that intakes of wholesome foods, seeds and nuts, legumes, fruits and vegetables were overall slightly lower than animal derived foods, like dairy, processed meat, eggs, poultry. Out of the pool of 72,149 participants, from the cohort of zero meat consumers, 31,124 were female, the average age was 57.3 years. 22,538 were at postmenopausal stage, 9812 were regularly exercising, 22,462 were taking multivitamins daily. 2698 had existed diabetes, 8328 had hypertension, 121 were currently smoking, 140 were currently consuming alcohol daily, the average BMI was 26.1 kg/m2 and the total energy (kcal) intake was 1901.3 with a deviation of 739.2. Data for Q1,

Q2, Q3, Q4 quartiles are vary for the same data points. Processed meat intake varied between 0g per day (zero intake) to 3.3g per day (Table 6) (Alshahrani et al., 2019).

Table 6: Chosen characteristics of the group cohort (N=72.149) by the consumption of unprocessed red meat (Alshahrani et al., 2019).

	Zero Intake	Quartiles of Intake g/day [1]			
Characteristic	**0**	**Q1**	**Q2**	**Q3**	**Q4**
Age (year), mean (SD) *	57.3 (14.0)	56.4 (13.8)	55.7 (13.4)	54.1 (12.7)	52.7 (12.4)
Female, *n* (%)	31,124 (66.8)	4306 (66.0)	4266 (66.9)	3989 (62.7)	3704 (58.2)
Blacks, *n* (%)	11,985 (25.7)	2089 (32.5)	2153 (33.8)	1805 (28.4)	1631 (25.6)
Married, *n* (%)	34,550 (74.1)	4409 (68.0)	4446 (69.7)	4565 (71.8)	4632 (72.7)
Graduate degree, *n* (%)	9956 (21.4)	987 (15.4)	903 (14.2)	817 (12.9)	684 (10.7)
Current multivitamin users, *n* (%)	22,462 (48.2)	3238 (50.4)	3086 (48.4)	2905 (45.7)	2790 (43.8)
Current smokers, *n* (%)	121 (0.3)	82 (1.3)	116 (1.8)	205 (3.2)	291 (4.6)
Alcohol daily users, *n* (%)	140 (0.3)	53 (0.8)	79 (1.2)	122 (1.9)	171 (2.7)
Exercise (≥150 min/week), *n* (%) [2]	9812 (21.1)	1109 (17.2)	1118 (17.5)	975 (15.3)	896 (14.1)
Postmenopausal, *n* (%) [3]	22,538 (72.4)	3082 (71.6)	3020 (70.8)	2744 (68.8)	2418 (65.3)
Current HRT users, *n* (%) [4]	11,659 (37.5)	1701 (39.5)	1682 (39.4)	1572 (39.4)	1348 (36.4)
Diabetes, *n* (%)	2698 (5.8)	636 (9.9)	692 (10.9)	711 (11.2)	698 (11.0)
Hypertension, *n* (%)	8328 (17.9)	1626 (25.3)	1635 (25.6)	1601 (25.2)	1649 (25.9)
Hypercholesterolemia, *n* (%)	7309 (15.7)	1439 (22.4)	1383 (21.7)	1326 (20.9)	1399 (22.0)
Current aspirin users, *n* (%)	6264 (13.4)	1233 (19.2)	1308 (20.5)	1236 (19.4)	1312 (20.6)
BMI (kg/m^2), mean (SD) *	26.1 (5.3)	28 (6.0)	28.7 (6.0)	29.2 (6.4)	29.9 (6.7)
Total energy (kcal), mean (SD) *	1901.3 (739.2)	1934.3 (800.7)	1853.7 (768.2)	1844.7 (777.6)	2071.2 (783.3)
Dietary variables (g/day), median, mean (SD) *					
Cruciferous vegetables	22.9 32.6 (32.1)	18.5 27.7 (29.7)	18.6 26.6 (27.4)	17.7 24.6 (24.2)	15.4 23.1 (26.7)
Fruits	306 356 (250.0)	246 302.7 (241.9)	231 281.9 (226.0)	199.1 243.2 (199.0)	155.9 200.3 (184.1)
Whole grain	162.1 185.4 (123.1)	122.1 149.4 (109.5)	107.7 139 (110.5)	92.9 120.5 (97.2)	77.5 102.3 (87.5)
Legumes	42.4 56 (48.0)	32.3 45.1 (43.6)	30.4 42 (41.9)	27.1 36.7 (36.9)	23.5 33.5 (34.6)
Nuts and seeds	20.21 25.34 (21.7)	14.06 19.80 (19.9)	12.33 17.89 (18.4)	11.55 16.33 (16.3)	9.82 14.58 (15.5)
Total dairy	46.8 115.7 (170.5)	143.6 199.1 (202.7)	163.7 215.1 (206.3)	178 228.1 (205.9)	184.1 232.9 (200.3)
Eggs	3.3 7.7 (13.3)	6.7 12.6 (17.4)	7.1 13.7 (17.6)	8.5 15.4 (18.5)	15.2 18.9 (23.7)
Unprocessed poultry	0 4.4 (13.9)	5.9 14.5 (20.5)	7.9 16.8 (21.1)	12.2 21.3 (22.4)	28.7 27.9 (23.3)
Processed meat	0 0.3 (2.5)	0.5 1.8 (5.6)	0.9 2.6 (6.0)	1.9 4 (6.9)	3.3 7.4 (12.7)
Fish	0 7.1 (17.3)	9.0 14.9 (20.7)	11.6 16 (19.5)	12.1 16.4 (18.9)	11.5 16 (18.8)

[1] Quartiles based on percentiles of the energy-adjusted g/day intake of unprocessed red meat among the total cohort. Median quartiles (g/day) are as follows, Q1 = 4, Q2 = 9.1, Q3 = 15.6, and Q4 = 41.7. [2] Exercise defined as "vigorous activities, such as brisk walking, jogging, bicycling, etc., long enough or with enough intensity to work up a sweat, get your heart thumping, or get out of breath". [3] Percentages were calculated among women only. [4] Current hormone replacement therapy users among postmenopausal women only. * SD: Standard deviation.

As shown in Table 7, model 1, within the whole cohort whereas altered to factors of sex, age, race and overall calories input, red and processed meat intake were linked to the chance of cancer fatality and cardiovascular disease, when utilizing all formations of exposure like zero vs. quartiles of consumption, p-trend, zero consumption vs. determined and undetermined 90th

percentiles. The connection between lower consumption and total and CVD caused death were mitigated but remained notable. Model 2 and 3 represents an alteration for other meats. The bigger chance of all caused mortality had been recognized for partakers in model 3 (other meats), uncalibrated, hazard ratio (HR) 1.18; 95% confidence intervals (CI) between 1.07 and 1.31 and calibrated, HR: 1.51; 95% CI: 1.22–1.98; $p < 0.001$) and CVD mortality (uncalibrated, HR: 1.26; 95% CI: 1.05–1.50 and calibrated, HR: 1.64; 95% CI: 1.09–2.57; $p = 0.017$). The combination of processed and red meat correlated with bigger probability of all cause death (Table 7). The chance of mortality for processed meat by itself was not related to mortality when it was altered to other meats (Alshahrani et al., 2019).

Table 7: Correlation between processed and red meat consumption and all cause, CVD & cancer mortality (Alshahrani et al., 2019).

	Unprocessed Red Meat Intake (g/day) [2]							
	Zero Intake	Quartiles of Intake [3]				*p*-trend	90th vs. 0 [4]	90th vs. 0 [4]
	0	Q1	Q2	Q3	Q4		Uncalibrated	Calibrated
No. of participants	46,613	6431	6377	6359	6369			
All-cause mortality								
No. of deaths (n = 7961)	5376	727	673	593	592			
Model 1	1.00	1.16 (1.07–1.26)	1.27 (1.17–1.38)	1.39 (1.27–1.52)	1.58 (1.45–1.72)	<0.0001	1.56 (1.46–1.67)	2.37 (1.99–2.93)
Model 2	1.00	1.08 (0.99–1.18)	1.16 (1.06–1.27)	1.19 (1.08–1.32)	1.26 (1.14–1.39)	<0.0001	1.25 (1.15–1.36)	1.69 (1.40–2.16)
Model 3	1.00	1.06 (0.97–1.17)	1.12 (1.02–1.24)	1.14 (1.02–1.27)	1.17 (1.05–1.32)	<0.001	1.18 (1.07–1.31)	1.51 (1.22–1.98)
CVD mortality								
No. of deaths (n = 2598)	1785	250	204	178	181			
Model 1	1.00	1.24 (1.08–1.43)	1.27 (1.09–1.48)	1.41 (1.20–1.65)	1.55 (1.33–1.82)	<0.0001	1.58 (1.40–1.78)	2.41 (1.86–3.24)
Model 2	1.00	1.20 (1.03–1.39)	1.18 (1.01–1.39)	1.27 (1.07–1.50)	1.32 (1.10–1.57)	<0.001	1.36 (1.18–1.57)	2.02 (1.44–3.04)
Model 3	1.00	1.15 (0.98–1.34)	1.11 (0.93–1.32)	1.17 (0.96–1.43)	1.20 (0.97–1.47)	0.051	1.26 (1.05–1.50)	1.64 (1.09–2.57)
Cancer mortality								
No. of deaths (n = 1873)	1228	175	160	159	151			
Model 1	1.00	1.13 (0.96–1.34)	1.16 (0.98–1.37)	1.38 (1.16–1.63)	1.53 (1.29–1.82)	<0.0001	1.50 (1.31–1.72)	2.17 (1.66–2.95)
Model 2 [5]	1.00	1.04 (0.88–1.23)	1.04 (0.87–1.24)	1.14 (0.95–1.37)	1.19 (0.95–1.37)	0.047	1.16 (0.99–1.37)	1.41 (0.98–2.05)
Model 3 [5]	1.00	1.01 (0.85–1.21)	1.00 (0.83–1.22)	1.08 (0.88–1.33)	1.07 (0.86–1.34)	0.357	1.04 (0.85–1.27)	1.18 (0.78–1.84)
	Processed Meat Intake (g/day) [2]							
No. of participants	48,127	6014	6044	6016	5948			
All-cause mortality								
No. of deaths (n = 7961)	5544	657	598	552	610			
Model 1	1.00	1.04 (0.96–1.13)	1.24 (1.14–1.35)	1.27 (1.16–1.40)	1.59 (1.46–1.74)	<0.0001	1.54 (1.43–1.66)	1.81 (1.59–2.12)
Model 2	1.00	0.98 (0.90–1.08)	1.10 (0.99–1.21)	1.09 (0.99–1.21)	1.27 (1.15–1.40)	<0.0001	1.20 (1.10–1.30)	1.38 (1.18–1.68)
Model 3	1.00	0.95 (0.86–1.05)	1.03 (0.94–1.14)	1.02 (0.91–1.13)	1.16 (1.04–1.29)	0.018	1.08 (0.98–1.20)	1.25 (0.95–1.94)
CVD mortality								
No. of deaths (n = 2598)	1821	224	199	176	178			
Model 1	1.00	1.11 (0.95–1.28)	1.32 (1.13–1.55)	1.38 (1.15–1.67)	1.53 (1.30–1.80)	<0.0001	1.54 (1.34–1.76)	1.90 (1.56–2.37)
Model 2	1.00	1.05 (0.89–1.24)	1.21 (1.02–1.44)	1.24 (1.01–1.51)	1.31 (1.09–1.57)	<0.001	1.28 (1.09–1.51)	1.68 (1.28–2.32)
Model 3	1.00	1.01 (0.84–1.21)	1.13 (0.93–1.37)	1.14 (0.92–1.42)	1.19 (0.97–1.47)	0.054	1.12 (0.93–1.36)	1.62 (0.97–3.71)
Cancer mortality								
No. of deaths (n = 1873)	1294	142	148	128	161			
Model 1	1.00	0.92 (0.77–1.10)	1.15 (0.95–1.39)	1.12 (0.92–1.36)	1.58 (1.32–1.88)	<0.0001	1.49 (1.28–1.73)	1.61 (1.28–2.04)
Model 2 [5]	1.00	0.85 (0.71–1.02)	1.00 (0.82–1.21)	0.94 (0.77–1.15)	1.19 (0.98–1.45)	0.229	1.12 (0.94–1.33)	1.09 (0.79–1.50)
Model 3 [5]	1.00	0.80 (0.66–0.96)	0.93 (0.75–1.14)	0.86 (0.69–1.06)	1.06 (0.86–1.32)	0.994	1.01 (0.83–1.23)	0.74 (0.32–1.38)

	Unprocessed Red Meat Intake (g/day) [2]							
	Zero Intake	Quartiles of Intake [3]				*p*-trend	90th vs. 0 [4]	90th vs. 0 [4]
	0	Q1	Q2	Q3	Q4		Uncalibrated	Calibrated
	Combined intake of red and processed meat (g/day) [2]							
No. of participants	40,287	7966	7965	7966	7965			
All-cause mortality								
No. of deaths (n = 7961)	4706	860	890	752	753			
Model 1	1.00	1.07 (0.99–1.15)	1.20 (1.11–1.30)	1.35 (1.24–1.46)	1.60 (1.47–1.73)	<0.0001	1.55 (1.45–1.65)	1.86 (1.68–2.09)
Model 2	1.00	1.03 (0.95–1.12)	1.11 (1.02–1.21)	1.18 (1.08–1.29)	1.27 (1.16–1.40)	<0.0001	1.25 (1.16–1.36)	1.44 (1.27–1.65)
Model 3 [6]	1.00	1.02 (0.93–1.12)	1.09 (0.99–1.21)	1.17 (1.04–1.30)	1.25 (1.12–1.40)	<0.0001	1.23 (1.11–1.36)	1.50 (1.26–1.83)
CVD mortality								
No. of deaths (n = 2598)	1564	291	290	230	223			
Model 1	1.00	1.11 (0.96–1.27)	1.27 (1.11–1.45)	1.38 (1.20–1.58)	1.56 (1.35–1.80)	<0.0001	1.57 (1.40–1.77)	1.90 (1.59–2.26)
Model 2	1.00	1.09 (0.93–1.27)	1.21 (1.04–1.40)	1.25 (1.07–1.47)	1.33 (1.12–1.57)	<0.0001	1.37 (1.19–1.58)	1.66 (1.32–2.12)
Model 3 [6]	1.00	1.08 (0.90–1.28)	1.18 (0.99–1.40)	1.21 (1.00–1.47)	1.29 (1.06–1.58)	0.005	1.34 (1.12–1.60)	1.73 (1.27–2.51)
Cancer mortality								
No. of deaths (n = 1873)	1080	196	206	194	197			
Model 1	1.00	1.00 (0.85–1.18)	1.12 (0.96–1.30)	1.25 (1.05–1.48)	1.57 (1.35–1.84)	<0.0001	1.48 (1.29–1.69)	1.73 (1.44–2.09)
Model 2 [5]	1.00	0.94 (0.80–1.11)	1.00 (0.85–1.18)	1.05 (0.88–1.26)	1.19 (1.00–1.43)	0.103	1.14 (0.97–1.34)	1.25 (0.97–1.60)
Model 3 [5,6]	1.00	0.88 (0.73–1.05)	0.92 (0.77–1.10)	0.97 (0.78–1.20)	1.07 (0.87–1.32)	0.604	1.00 (0.82–1.22)	1.02 (0.70–1.42)

The data is based on hazard ratio, values were given on energy-altered variables. Quartiles are percentiles of the energy-adjusted g/day intake of total cohort. Median quartiles (g/day) are as follows, for unprocessed red meat, Q1 = 4, Q2 = 9.1, Q3 = 15.6, Q4 = 41.7; for processed meat, Q1 = 0.7, Q2 = 1.4, Q3 = 3.3, Q4 = 9.4; and for combined consumption of red and processed meats, Q1 = 1.4, Q2 = 7.3, Q3 = 15.4, Q4 = 42.8. Model 1 was altered for gender (male and female), age, race (black & non-black), and overall energy consumption. Model 2 was altered for gender (male and female), age, race (black and non-black), and overall energy consumption, marital status (married, separated, single, widowed, divorced), level of education (graduation from secondary school, college, bachelor, master, graduate degree), use of multivitamin supplement, level of smoking (ongoing, quit smoking), fruit intake (Quintiles: 224.4–322, >322–464.2, >464.2), consumption of whole grain (Quintiles: 109.9–170.3, >170.3–252.2, >252.2), consumption of legumes (Quintiles: 29.7–45.9, >45.9–77.1, >77.1), intake of nuts and seeds (Quintiles: 12.8–21.6, >21.6–35.1, >35.1), overall dairy consumption (zero consumption, quartiles of consumption: >0–36, >36–108.1, >108.1–240.9, >240.9), consumption of eggs (zero consumption, quartiles of consumption: >0–3.6, >3.6–7.3, >7.3–20.1, >20.1). Status of menopausal (pre and post) and level of hormone therapy was altered for women (on therapy – off therapy). Model 3: altered for other meat options, like fish (zero consumption, quartiles of intake: >0–7, >7–12.6, >12.6–21.4, >21.4), & non processed poultry (zero consumption, quartiles of intake: >0–4.8, >4.8–10.4, >10.4–32.5, >32.5). Non processed red meat and processed meat were altered (0 consumption and quartiles of input) & vice versa. Models in these data assessment were corresponding to models 1, 2, & 3, except for 90th percentile for non-processed red meat: 46.5 g/day; & for processed meat: 11 g/day; & for combined input of red & processed meats: 49.1 g/day). Data was altered for earlier conducted test for cancers such as colon, breast or prostate throughout the past 4 years (Alshahrani et al., 2019).

As shown in Figure 6, subgroup results were depicted as forest plots, in which zero consumption vs. 90^{th} percentile variance were used. Amidst the women cohort, risk of all - cause mortality was correlated with non-processed red meat (HR: 1.17; 95% CI: 1.03–1.33), amidst men (HR: 1.21; 95% CI: 1.03–1.43), & amidst non-Blacks (HR: 1.20; 95% CI: 1.06–1.34), but not amidst blacks (HR: 1.18; 95% CI: 0.96–1.45); with CVD mortality amid women (HR: 1.30; 95% CI: 1.03–1.64), but not amid men (HR: 1.15; 95% CI: 0.93–1.79), and amidst blacks (HR: 1.69; 95% CI: 1.18–2.40), but not amidst non-blacks (HR: 1.17; 95% CI: 0.95–1.43). Processed meat was correlated with all-cause death amid women (HR: 1.17; 95% CI: 1.03–1.32), but not men (HR: 0.99; 95% CI: 0.84–1.16), and amid blacks (HR: 1.21; 95% CI:

1.00–1.47), but not amid non-blacks (HR: 1.03; 95% CI: 0.92–1.15); with CVD deaths amid women (HR: 1.32; 95% CI: 1.06–1.66), but not amid men (HR: 0.87; 95% CI: 0.64–1.20), blacks (HR: 1.07; 95% CI: 0.74–1.55), nor amid non-blacks (HR: 1.10; 95% CI: 0.89–1.36). The integrated consumption of red and processed meat was correlated with a higher risk of all-cause mortality amid all cohorts & CVD mortality amidst women and blacks (Alshahrani et al., 2019).

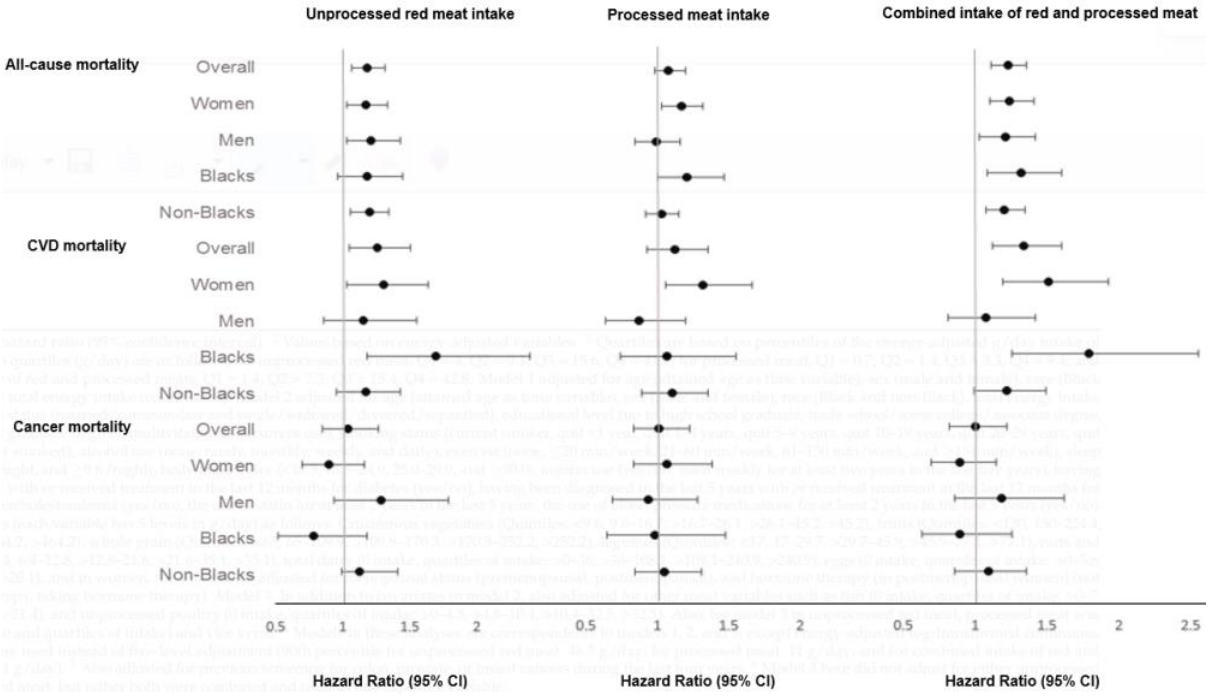


Figure 6: Gender and race subgroup examination between consumption of red and processed meat along with all-cause mortality, CVD mortality & cancer mortality (Alshahrani et al., 2019).

The data analysis was altered for gender (male and female), age, race (black and non-black), and overall energy consumption, marital status (married, separated, single, widowed, divorced), level of education (graduation from secondary school, college, bachelor, master, graduate degree), use of multivitamin supplement, level of smoking (ongoing, quit smoking), level of exercise, BMI, use of medication like aspirin, blood pressure drugs, status of menopausal in women, dietary intakes of fruits, vegetables, fish, seeds, nuts, legumes, grains, dairy. In conclusion, lower intake of red and processed meat consumption in contrast to zero intake has been associated with greater risk of cardiovascular and all-cause mortality (Alshahrani et al., 2019).

2.2.2.2 The Association of Plant Based Diet with CVD and Mortality

Managing the risk of cardiovascular diseases became one of the biggest challenges nowadays. In 2019, 32% of total deaths were caused by CVD globally. Diet became the key risk factor which significantly effects the chance of CVD development. With the rapidly expanding popularity of plant-based diets, studies have been conducted to support the growing evidences about the risk factors between PB diet and CVD, mortality and stroke. PB diet is based on 100% food which derived from plants only, while vegetarian diet would limit the animal derived food intake. A higher level of plant-based food consumption has been linked to help reducing blood pressure, triglyceride levels in plasma, therefore it can help fighting against overweight and obesity, and lowering a risk of diabetes. Plant derived food diet has been linked with a higher energy level which improves the quality of life, better sleeping functions and mental health (Quek et al., 2021).

There have been several studies conducted over the years about vegetarian and plant-based diet and its association with CVD. A study highlighted, that vegetarians who don't eat meat but still consume animal products such as dairy, had a lower risk of developing heat disease by 29% compared to people on omnivorous diet. As a contrary another study had been conducted about PB diet, which revealed that there was no significant difference about CVD development amid people diagnosed with diabetes, compared to people following omnivorous diet. Plant-based foods and diets are widely varied from raw, wholesome, mainly based on fruits and vegetables foods to fully processed, refined sugary, full fat unhealthy plant-based versions, hence differentiation within PB diet is necessary to clearly associate connections between PB diet and CVD mortality. Plant-based dietary index (PDI) has been created to furthermore classify differences within levels of PB diet scores. The assessment of PDI is based on healthy and unhealthy characteristics (Quek et al., 2021).

A study had been conducted which underwent an assessment of relation between plant-based diet and risk of CVD involving 410,085 partakers. The PB diet included both, vegetarians and vegans also. The aim was to adhere to a PB diet, while consuming more plant foods against animal derived foods, in vegans, zero intake of animal sourced foods. The study was looking for outcomes of healthy PDI (hPDI) vs. unhealthy PDI (uPDI) and their relation to risk of CVD, CVD caused mortality and stroke. Roughly 78.000 people were categorized as either vegetarian or vegan. The studies originated from Europe, North America and Asia. The standard features and the evaluation of the studies are summed up in Table 8. The mean BMI ranged between 23

to 29.7 kg/m2, and the mean age of the partakers ranged between 38 to 67 years. The evaluation of the studies was mostly based on questionnaires, component investigation, partakers dietary consumptions and some studies were assessed partakers who are only following healthy plant-based, unhealthy plant-based dietary habited people (Quek et al., 2021).

Table 8: The abstract and main characteristics of the evaluated studies (Quek et al., 2021).

Year	Region	Sample Size	Mean Age	Gender (male)	Body Mass Index	Smoking History	Dietary Assessment Method	Exposure	Level of Intake Category
2020	Europe	30,410	56.8	0.358	26.0	0.54	Oxford WebQ	hPDI	Quintile
2020	North America	248,029	45.9	-	24.2	0.479	FFQ	PDI, hPDI, uPDI	Quintile
2020	Asia	4,143	51.4	0.269	23.0	0.0962	FFQ, Interview	Vegetarian	-
2019	North America	5,128	63	-	25	0.53	FFQ	PDI, hPDI, uPDI	Quintile
2019	North America	8,740	38.9	0.596	-	0.152	FFQ, Interview	PDI, hPDI, uPDI, Provegetarian	Quintile
2019	North America	16,068	64.9	0.339	28.6	0.074	FFQ	Plant-based	Quartile
2019	Europe	16,254	39.4	0.247	23.0	0.104	FFQ	Vegetarian	-
2018	North America	11,879	48	0.48	-	0.15	FFQ, Interview	PDI, hPDI, uPDI	Decile
2016	Europe	20,324	43.4	0.247	23.5	0.165	FFQ	Vegan	-
2015	North America	4,353	-	0.336	27.8	0.073	FFQ	Plant-based	Quartile
2014	Europe	1,731	67.4	0.424	29.7	0.118	FFQ, Interview	Provegetarian	-
2013	North America	5,076	-	0.37	-	0.07	FFQ	Plant- based	Quartile
2013	North America	37,950	57.8	0.344	25.9	0.138	FFQ	Vegetarian	-

There have been two ways of approaching the linkage between CVD and PB diet. When an overall PDI was assessed by the studies, there was no significant difference administered in CVD mortality. However, when uPDI and HPDI were contrasted in the studies, uPDI demonstrated a notable increase of CVD mortality risk compared to hPDI. Hazard Risk ratio for unhealthy PDI ranged between 1.02% to 1.08% compared to healthful PDI, where this ration ranged between 0.86% to 1.02%. Average 0.91percentage versus 1.05 percentage. (Figure 7) (Quek et al., 2021).

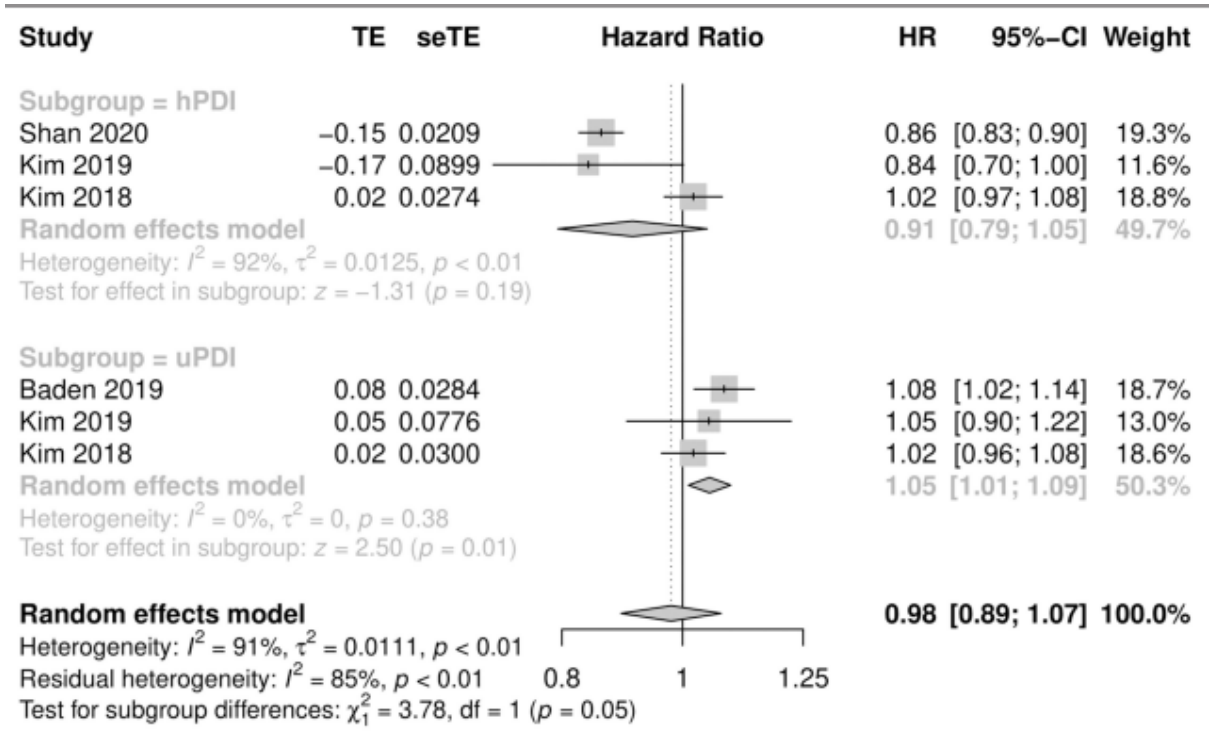


Figure 7: CVD mortality comparison by hPDI and uPDI (Quek et al., 2021).

The study overlooked the relationship between vegetarians and meat eaters. In CVD mortality there was no notable decrease for vegetarians, although participants who followed vegetarian diet had an important lowered risks in CVD compared to people whose main consumption was meat. There were minor differences in risk of stroke, haemorrhagic stroke, ischemic stroke between vegetarians and meat eaters. Previously evaluated reports mainly focused on vegetarian diets and its linkage to CVD compared to mainly meat-based diets, however the study from (Quek et al., 2021) is mainly focused on a greater bond to plant-based diet and determines that, by mostly consuming plant-based food only the risk of CVD and CVD mortality can be greatly reduced. Healthful foods like wholegrains, vegetables, legumes, fruits, nuts supported a low risk of CVD development between 8.1 percent to 10.2 percent (Table 9) (Quek et al., 2021).

In conclusion, adherence to a vegan plant-based diet can significantly reduce the risk of developing CVD and mortality by CVD. Not all plant-based foods are healthy, refined sugar, refined carbohydrates, saturated fats and oils in vegan foods can have detrimental health effects, hence prioritising healthful foods consumption is essential (Quek et al., 2021).

Table 9: Sum of CVD and CVD death result (Quek et al., 2021).

	Cardiovascular Mortality						Cardiovascular Disease					
	Number of Studies	Number of Patients	HR (95% CI)	I^2	Cochran Q	*p*-value	Number of Studies	Number of Patients	HR (95% CI)	I^2	Cochran Q	*p*-value
Overall	7	124 501	0.919 (0.856–0.986)	88.50%	<0.0001	**0.0193**	7	323 854	0.898 (0.821–0.981)	87.20%	<0.0001	**0.0173**
PDI[b]	3	28 844	0.896 (0.762–1.05)	91.70%	<0.0001	0.184	2	211 585	0.881 (0.806–0.963)	34.20%	0.218	**0.0054**
Vegetarian Diet[c]	2	58 274	0.887 (0.782–1.01)	0.00%	0.639	0.0611	1	16 254	0.810 (0.721–0.911)	22.20%	0.257	**0.0004**
By Healthful vs. Unhealthful PDI						**0.05[a]**						0.18[a]
hPDI	3	52 770	0.912 (0.794–1.05)	92.10%	<0.0001	0.190	3	71 301	0.870 (0.800–0.946)	57.50%	0.0949	**0.0011**
uPDI	3	18 966	1.05 (1.01–1.09)	0.00%	0.384	**0.0123**	2	221 177	1.11 (0.787–1.56)	95.50%	<0.0001	0.555

p-value < 0.05 is significant; HR, hazard ratio; CI, confidence interval; PDI, plant-based dietary index; hPDI, healthful plant-based dietary index; uPDI, unhealthful plant-based dietary index; [a]Denotes p-value comparing subgroup difference between hPDI and uPDI; [b]Highest quintile/tertile vs. lowest quintile/tertile; [c]Vegetarians vs. regular meat eaters. Bolded values denote that p-value < 0.05.

Vegetarians, but especially vegans are widely known of their metabolic vitamin B-12 deficiency. A vegan diet which is lacking of vitamin B-12 along with a higher sodium intake can produce detrimental cardiovascular events. Vitamin B-12 fortified foods and supplementation is essential in order to keep a low risk of developing CVD and CVD mortality (Woo et al., 2014).

2.3. Eating Motivations Behind Omnivores and Vegans

Although eating meat has always been the main element of our diet, the spread of plant - based foods has significantly grown, resulted millions to follow a vegan diet especially in the recent years. A recent survey in the U.S, showed that approximately 5% of the population followed a vegetarian diet and roughly 3% followed a vegan diet in 2018. The percentages seem to be a minor number, this still means that a good few millions of people are following a meat free diet. There has been a contemplation about what makes people eat what they eat, what are the main motives for omnivorous and veg*ns, what makes them eating meat and why would veg*ns not eat meat. Veg*ns as a word, combines vegetarians and vegans. Getting to know the

eating habits and motives from both sides, can help understanding and develop future diet possibilities and products (Müssig et al., 2022).

A study showed, that since the main difference between the omnivore and veg*n diet is the presence of animal derived elements, animal welfare and the ethics are the main motivations for veg*ns to follow this lifestyle. The first core principle is protecting animals. It is followed by a health-conscious motivation, expected health benefits by avoiding meat consumption corroborated by several studies. The spectrum of eating motives for veg*ns has broadened up, particularly since the perceived rise of global warming, environmental motives became major for veg*ns. Based on this study other than these motives, religious beliefs, weight loss desire and the cost of food are also motivating veg*ns to follow a meat free diet (Müssig et al., 2022).

As contrary to the motivations for veg*ns, the motivations for omnivores were exposed as the four Ns, which stands for eating meat is Nice, Necessary, Normal and Natural. In the recent years, multiple studies searched for answers about eating motives. One of study revealed, that the main motivations for omnivores for meat consumptions were fondness, health awareness, desire to be full after eating and social believes and norms. Another study interviewed 707 people personally about their eating motive. The consumption of natural food was the main trigger for vegetarians and vegans compared to the omnivores. Common motivations were found across several studies for omnivores, they believed that eating meat is healthy, convenient, cost less, can help reduce weight, meat taste good and mainly it is full of essential nutrients. As a contrary, veg*ns believe that avoiding meat is healthy, more ethical, more sustainable for the environment based on several studies conducted (Müssig et al., 2022).

In a recent study conducted in Germany in 2022, Müssig et al., 2022 discussed dissimilarities and similarities in eating motives of veg*ns and omnivores. Eighteen individual statements were asked in the survey for comparison, and the responds were displayed in rank order context to highlight the mean difference of responses. 619 people took part of the survey, mainly from universities and social media groups via emails. 615 partakers completed the survey, 81.4% of them were female, and 18.6% male. The mean age of the interviewees was 31 years. The participants responded with their dietary categories, which resulted in 103 people were omnivore, 24 pescatarian, 167 flexitarian, 85 lacto - ovo vegetarian, 5 ovo – vegetarian, 17 lacto – vegetarian, 68 vegan and 146 ethically motivated vegan. The participants ended up in 2 final groups, the omnivores group (including the flexitarians and pescatarians) with a total of 294 and the veg*ns group (all other categories) with a total of 321 people. The survey was

based on and the results ranked by 18 eating motivations. These 18 motives were liking, environmental protection, habits, animal protection, hunger and need, religion, health, social image, convenience, social norms, pleasure, regulation affects, traditional eating, weight control, natural concerns, visual appeal, sociability and price. The motives were answered on a liking scale between 1 to 7, where 1 reflects never and 7 reflects always. Each motive factor included a minimum of 3 questions, phrased in a way of, I eat what I eat because… and selection of answers were given for the partakers (Table 10).

Table 10: Survey sample questions (Müssig et al., 2022).

Assumed Factor	Item (I eat what I eat because …)
Religion	… because I follow religious rules by doing so
	… because my religion requires me to abstain from certain foods
	… because my religion dictates the consumption of certain foods
Animal Rights	… because animal welfare is important to me in the production of my food
	… because it is important to me that farm animals are slaughtered humanely
	… because important animal welfare standards are adhered to by doing so
	… because as much attention as possible is paid to the needs of animals by doing so
	… because animals suffered as little pain as possible by doing so
Environmental Protection	… because it was produced in an environmentally friendly way
	… because the rainforest is not cleared to make it
	… because it has a low carbon footprint
	… because little drinking water is used to produce it
	… because it is produced regionally
Global impact	… because I do not want to support the exploitation of people
	… because by doing so I contribute to a more peaceful world
	… because it is important to me not to waste resources
	… because it corresponds to my ethical values
	… because it corresponds to my political values

The result of the survey shows, that the main motivations for the omnivores were liking (mean value on the liking scale of 1 to 7 was 6.20), need and hunger (5.57), health (5.23). Similarly, the first motive for the veg*ns group was liking (6.16), followed by health (5.73) and animal protection (5.70). The least motives for both groups were religious (combined value of 1.15), social image (combined value of 1.70) and social norms (combined value of 2.21). Veg*ns showed an overall motivation towards health, animal and environmental protection and natural foods, compared to the other group, while omnivores were extra motivated by habits, traditions and norms than the veg*ns (Table 11) (Müssig et al., 2022).

Table 11: Survey result of the average differences in eating motives between omnivores and veg*ns (Müssig et al., 2022).

	Total sample		Omnivores		Veg*ns				
Motive	***M***	***SD***	***M***	***SD***	***M***	***SD***	***t***	***p***	***d***
Liking	6.18	0.76	6.20	0.75	6.16	0.78	0.66	0.507	0.05
Habits	4.54	1.30	4.86	1.23	4.25	1.29	6.04	<0.001	**0.48**
Need & Hunger	5.55	0.91	5.57	0.86	5.52	0.95	0.69	0.493	0.06
Health	5.49	1.14	5.23	1.17	5.73	1.05	−5.54	<0.001	**−0.45**
Convenience	4.67	1.38	4.71	1.46	4.63	1.30	0.69	0.488	0.06
Pleasure	4.79	1.23	4.83	1.24	4.77	1.23	0.59	0.554	0.05
Traditional Eating	3.28	1.50	4.09	1.34	2.55	1.22	14.95	<0.001	**1.20**
Natural Concerns	5.09	1.43	4.72	1.54	5.43	1.23	−6.31	<0.001	**−0.51**
Sociability	4.09	1.56	4.37	1.59	3.83	1.50	4.33	<0.001	**0.35**
Price	3.68	1.47	3.83	1.51	3.54	1.43	2.41	0.016	0.20
Visual Appeal	2.94	1.25	3.09	1.30	2.80	1.18	2.85	0.005	0.23
Weight Control	3.66	1.54	3.67	1.61	3.66	1.48	0.14	0.890	0.01
Affect Regulation	2.48	1.48	2.41	1.45	2.54	1.51	−1.12	0.261	-0.09
Social Norms	2.21	1.16	2.47	1.24	1.97	1.03	5.39	<0.001	**0.44**
Social Image	1.70	0.88	1.74	0.90	1.66	0.86	1.03	0.303	0.09
Religion	1.15	0.63	1.17	0.66	1.13	0.61	0.69	0.490	0.06
Animal Protection	5.09	1.64	4.43	1.55	5.70	1.47	−10.44	<0.001	**−0.84**
Environmental Protection	4.55	1.53	3.74	1.38	5.29	1.26	−14.56	<0.001	**−1.18**

*N (Omnivores) = 294, N (Veg*ns) = 321. Effect sizes printed in bold are significant at p <0.001. Eating motives were answered on a 7-point Likert-type scale (1 = never, 7 = always). In control analyses including age as a covariate, the results were virtually identical.*

In conclusion, the result of this online survey showed, that the participants from both dietary groups ate what they ate because they simple like their food and believe that is healthy for them. As it was expected, the motivations about animal welfare, sustainability and natural concerns were more important and relevant for the people from the veg*ns group, while for the people who followed an omnivorous diet, motivations like social norms, traditional eating were more applicable. This study represented a wider insight what really motivates people when they can freely choose their diet based on their believes and commitments. Future studies may further investigate these habits and motives to increase understanding the changes leads to people choose their dietary motives (Müssig et al., 2022).

Chapter 3 – Plant Based Meat and Vegetable Patty Alternatives, Mimicking the Meat Effect

The global environmental sustainability programme planning and the preservation of food availability for the future must consider changes in our nourishment. “What nourishing food we can eat” became one of the most concerned questions in field of sustainability recently. Based on scientific researches conducted in the field, nutritional intervention is needed to supply the growing demand for food. This change would involve a decrease in animal farming and keeping the ecological system within thresholds, introducing alternative solutions to mitigate the pressure on the animal agriculture sector, particularly on beef cattle, to serve the high demand for meat. The idea of balancing the food supply and food demand and environmental sustainability is not novel. There have been actions and considerations take since the 1970s, but the actions taken were mainly focused on yield and production increase, but examination of food systems were not in their focus. Mainly nutritional linkages between ingredients and effects of different diets were in the middle of the focus. Food consumption, production, nutrition and dietary intervention combined need to be addressed to mitigate the environmental burdens (Peters et al., 2016)

3.1. The Flagships of “Alternative” Meat and Veggie Patties: Impossible Burger, Plant-It Burger and Strong Roots Vegetable Burgers

All three of the named plant - based burger brands, The Impossible Burger (IB), the Plan-It Burger and the Strong Roots Vegetable Burgers are 100% plant - based, all ingredients are derived from plants only, suitable for vegans. Their look, texture, smell, and taste are very closely resembled to a traditional beef burger patty, with an important difference of their origination, except the Strong Roots vegetable burgers as they made of vegetables only. All three brands provide cruelty free burgers, means no animals had to be slaughtered. The IB is made in the USA, while the Plant – It and Strong Roots products are made in Ireland, which also gives a strong point to the sustainability point of view, as the burgers are potentially consumed in Ireland.

3.1.1 Impossible Burger

The star product of Impossible Foods company is the IB. It was created to mimic a conventional beef burger patty with a wide variation of usage range. Image 1 & 2 show the in store 2 packs and block burger patties, Image 3 depicts the IB patty in a burger.

Image 1: The IB Patties retail packaging (https://impossiblefoods.com/products/burger/patty-2-pack).

Image 2: Impossible burger patties on the shelf (https://www.forbes.com/sites/lanabandoim/2019/12/20/what-the-fdas-decision-about-soy-leghemoglobin-means-for-impossible-burger/?sh=6d3dc9b357f6).

Image 3: The Impossible Burger patty in a burger (https://impossiblefoods.com/products).

The burger patty can be easily used to make burgers, tacos, sauces, meatballs, etc. The main ingredients of the burger are proteins derived from plants, oils, fats, binder components, besides a unique ingredient of heme, which gives the meat feeling (texture, juiciness, flavour, colour) to this plant burger. As shown in Figure 8, all ingredients are combined together to create a mass, which then is formed to the desired shape and some products are frozen before packaging. Heme is manufactured separately, the process involves fermentation and isolation. The provided process flow refers to the manufacturing of the raw ingredients, heme creation, then the production of the burger itself as well as the wrapping (Khan et al., 2019).

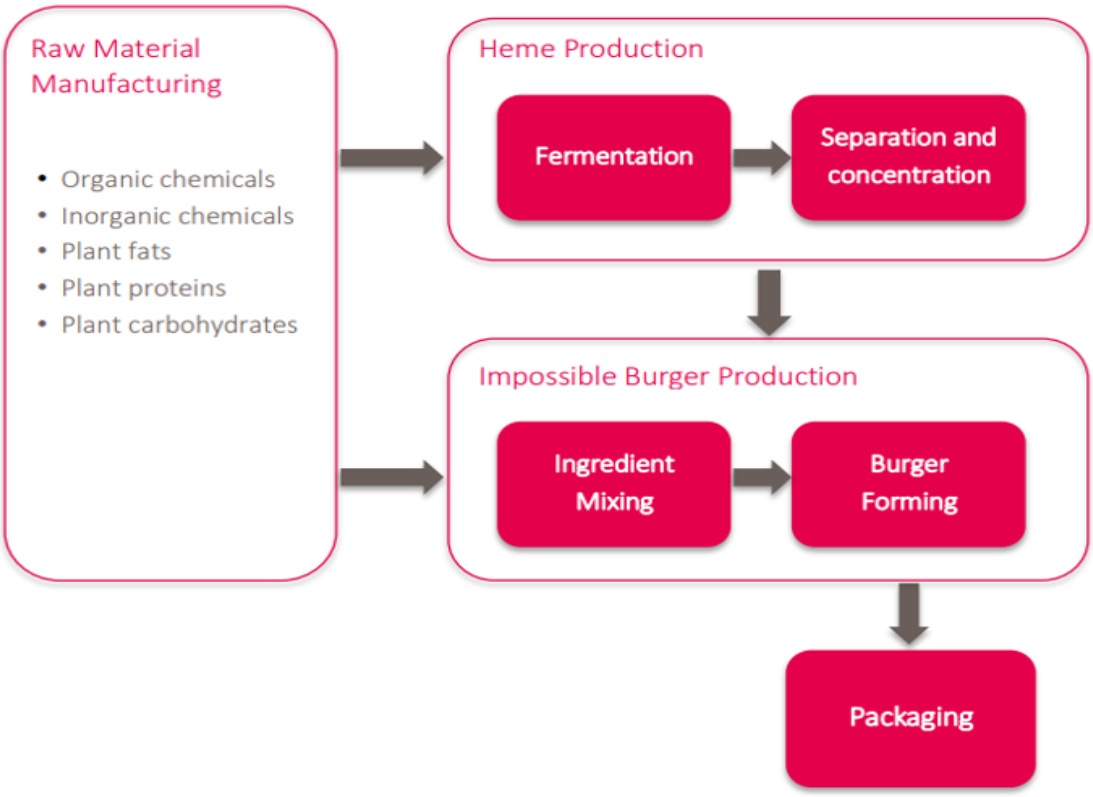


Figure 8: Manufacturing process flow of IB, raw material inputs & conveyance (Khan et al., 2019).

As it can be seen in Table 12, the nutritional content comparison for both the Impossible burger and the regular beef burger with 20% fat and 80% lean meat, mainly shows deviation in the figures. The calories and the PDCAA (Protein Digestibility-Corrected Amino Acid Score) are nearly similar, but much bigger difference can be seen in cholesterol (0mg for IB, 71mg for beef). The Impossible Burger provides a lesser fat content (14mg vs 20mg) and higher protein value (19mg vs. 17.17mg). Cooking time and shelf life is similar in both (Khan et al., 2019).

Table 12: Nutrient content of IB & Beef Burger with 20% fat (Khan et al., 2019).

Nutrition Content	Impossible Burger® (4 oz.)	Beef burger 20% fat (4 oz.)
Calories	240	254
Total fat (g)	14	20
Cholesterol (mg)	0	71
Protein (g)	19	17.17
Total Carbohydrate (g)	9	0
PDCAAS*	0.83	0.85

** Protein Digestibility-Corrected Amino Acid Score: measure to evaluate protein quality based on humans' amino acids requirements and its digestibility*

Image 4: IB cooking instruction, ingredients list and nutrition facts table with daily value % (https://shopsmart.guide/grocery/impossible-burger-ground-beef/)

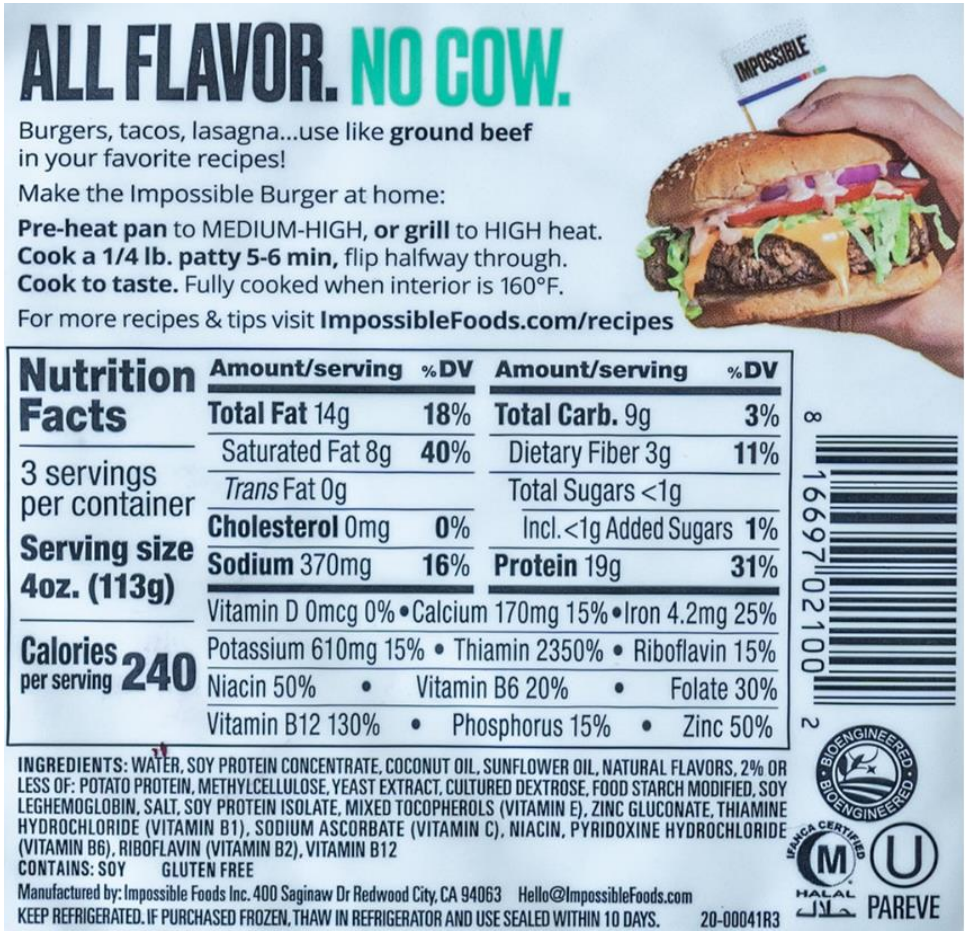


Image 4 depicts the cooking instruction, ingredients list and a detailed nutrition facts table with daily value percentage. The burger is fortified with different kind of vitamins, which are particularly important for vegans as they tend to lack of certain vitamins and minerals especially iron, calcium and vitamin B12, due to not consuming animal sourced food. One of the big advantages of IB is the 0mg of cholesterol. Regular meat products contain high amount of cholesterol which needs to be maintained and kept low to avoid any potential cardiovascular diseases, high cholesterol, etc.

Ingredients:

1. **Protein**

As we can see in the ingredients list, the protein content derives from potato and soy, which make the burger meaty and gives the necessary nutrient content. Soy is quite controversial in many people mind due to its high level of isoflavones.

As per the Impossible Burgers website's soy facts and why it's in the product blog (https://impossiblefoods.com/blog/soy-facts-myths-and-why-its-in-our-new-recipe), over 15 thousand of peer reviewed essays have been authored about its healthy and nutritious act after constant researches. Soy has been nourishing the mankind over centuries. Soybean is famous for being a high-quality protein which is known to have similar attributes as an animal derived protein, like digestibility, score of the amino acids (PDCAAS). Beef has a 0.92 PDCAA, as contrasted to soy, which presents a PDCAAS range between 0.91 to 1.00, depending on the type of soy product. Soy is also a great fibre, and minerals source, especially iron, phosphorus, magnesium & potassium.

Soy has developed some safety concerns over the years without any major scientific research which would support the opposite, only very list or non-basis in fact. It has been claimed that soy may causes breast cancer, reduces male fertility, impedes the normal functionality of thyroids. Most of the concerns are generated from the certainty, that soy is high in isoflavones, which is a class of a plant estrogen (phytoestrogen). This plant estrogen has a similar structure as a female sex hormone. This can have a promoting or blocking effect when binding the estrogen receptors. Isoflavones earned a badge of the main cause of all worry about soy. In the western culture the average range of isoflavone intake is 1 to 3mg per day, where this level in Asia, varies between 25 to 50 mg per day. IB contains less than 2 mg of isoflavones. One of the main concerns about isoflavones that it causes breast cancer for women, however there has been no scientific evidence backed up this theory. On contrary, scientific investigations suggest

that it mitigates the chance of breast cancer. Japanese people consume 6 to 11 gram of soy daily which supports the prevention of breast cancer or the reappearance if already diagnosed and healed. It has also been also stated that soy protein and / or isoflavones negatively interferes to male hormones and affects fertility. As per up to best knowledge, there have been no studies to prove that either of them would have anti effect on hormone levels. Two cases have been reported when during an enormous amount of daily intake of soy, malfunctions occurred which got resolved when soy intake stopped. One of the other main concerns about soy is that it causes malfunction in the function of thyroids. After many trials which were conducted to test the soy effect on thyroid functions, there were no detrimental result reported. Soy has been consumed over centuries with a clear history, including infant formulas, it can be concluded that the soy used in Impossible food products, including the IB, it's not just a high-quality protein with great nutrient benefits, but it is also a great source of fibre and a required microelement (https://impossiblefoods.com/blog/soy-facts-myths-and-why-its-in-our-new-recipe).

2. Flavour

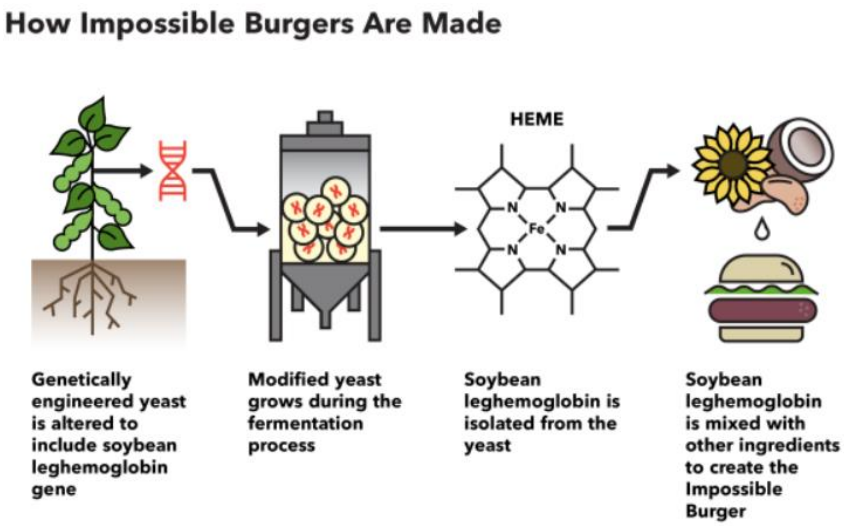
One of the main objectives when it comes to food is the taste, the flavours, how tasty the food is, as taste will give the overall satisfaction for the consumers.

The IB is made of clean and straightforward components. The protein derives from potatoes, wheat and soy, the main fat in the burger is coconut oil. It contains simple sugars, and also fortified with minerals, vitamins and iron. All these ingredients are also found in healthy foods we usually consume. The key ingredient which makes this burger meaty, juicy is heme. It gives all the characteristics to make it resemble to meat (https://impossiblefoods.com/blog/soy-facts-myths-and-why-its-in-our-new-recipe).

Heme has been around in nature everlastingness, it's been taking a key part in each plant and animal cells. Heme has the ability to carry oxygen across the body in the bloodstream, approximately as much in the blood as it would be in 136 kg of Impossible Burger. Heme in animal tissues are in charge of to give the unique meaty taste to the meat. During the process of cooking, heme enhances the flavour. Hence, heme is also the key element in mimicking the beef burger. Plants are also containing heme proteins, the closest match to the animal heme was found in legumes' roots, called leghemoglobin. When leghemoglobin was combined with the other natural ingredients IB contains it also enhanced the flavour and gave the unique meaty characteristics, such as reaction to cooking, appearance, fragrance to the Impossible Burger. Leghemoglobin was analysed if it's suitable for human consumption from toxically, safety,

allergenic point of view, to ensure it fits for the purpose without causing any potential illnesses and it's safe to consume (https://impossiblefoods.com/blog/soy-facts-myths-and-why-its-in-our-new-recipe).

Image 5: IB production flow focusing on soy and heme (https://news.bloomberglaw.com/health-law-and-business/impossible-foods-tests-a-tastes-like-meat-patent-in-court)



The FDA (Food & Drug Administration) has cleared the challenges against the genetically produced soy leghemoglobin. It's been declared safe for human consumption. Soy protein and soy leghemoglobin are the two genetically manufactured component in Impossible Burger. As it can be seen in Image 5, yeast producing gives the gene to create the soy leghemoglobin. Yeast got injected by the DNA of the soy leghemoglobin, then after a fermentation and isolation process, the soybean leghemoglobin is ready to be added to the IB. The main reason behind this process is sustainability, as harvest of the actual soybean can be waived. The Impossible Foods company assures the safety of the soy leghemoglobin consumption. There had been an objection around the genetically engineered heme to be used as a food additive for colouring purposes to potentially be an allergen, but this challenge had been cleared by the FDA to confirm that yeast protein doesn't cause allergic reactions, hence it isn't a prime allergen (https://news.bloomberglaw.com/health-law-and-business/impossible-foods-tests-a-tastes-like-meat-patent-in-court).

3. Fat & Binders

Coconut oil has become a popular ingredient in the vegan world, the fat content in Impossible Burger derives from coconut along with sunflower oil. Fats also take an important part to make the burger juicy and tasty. Food starch such as potato, corn as well as methylcellulose bring the

burger bind all together. These binders are widely used in confectionary, like in ice creams, or in soups as well as an example (https://impossiblefoods.com/blog/soy-facts-myths-and-why-its-in-our-new-recipe).

3.1.2 Plant-It Burger

The Plant-It food company is one of Ireland's first meat substitute brand. Their business is driven by the motto of choose good, do good (Image 6). It refers to the fact, that the products are plant – based and cruelty free, hence they are more sustainable and animal friendly and refers to their tree planting activity. It was launched recently in 2019, when two food businesses merged together, both companies had huge experience in Irish food business. The company similarly to Impossible Foods, manufacturers meat substitutes, like mimic burger patties, steaks, minced meat alternatives, no chicken goujons, burgers, fillets, fish free goujons, egg free omelette, quarter pounder. The company was rewarded with two awards recently, Ireland's favourite meat alternative brand and the quarter pounder won the best sustainable food product title (https://plantbased.ie/news/award-winning-irish-brand-plantit-launches-in-the-us/).

The company has launched its business in the U.S. through their partners. Launching a new product in U.S. is quite challenging, due to the regulations and competitors, just to name Beyond Burger and Impossible Foods. One of the advantages that Plant-It had a grip on is their purpose led sustainability strategy. Plant -It plants native tress across Ireland, UK and Finland after their sales. The company planted over 20.000 trees so far (https://www.checkout.ie/a-brands/meet-the-makers-plant-it-all-over-the-world-160569).

The products are 100% vegan, cruelty free, non - GMO, meat-like textured, fortified by B12 and other vitamins and use 100% recyclable packaging (https://www.plantit.com/).

Image 6: Plant-It company logo and motto (https://www.plantit.com/).

3.1.3 Strong Roots Veggie Burgers

One of the leading plant - based food companies in Ireland is Strong Roots (SR) who offers sustainably grown and manufactured plant – based frozen food products, established in 2015. Their goal was to revolutionize the frozen food sector in food business and they became one of the fastest growing international company these days. Strong Roots has a wide range of frozen vegetable food products, like hashbrown, chips, veggie burgers, snacks, etc. (Image 7) They recently secured a 55 million dollars investment funding from McCain foods which opened a whole new possibility for the future of the company and for a strategic partnership between the two companies. (https://vegconomist.com/interviews/strong-roots-on-track-to-becoming-one-of-the-most-recognizable-frozen-food-brands-globally/).

McCain Foods is one of the largest frozen food companies in the business. Their investment to Strong Roots will support the worldwide expansion of Strong Roots products, by being McCain Food the largest potato based frozen food company in the world and their products being available in 160 countries. The two companies will continue growing their own separate businesses, even though they offer similar product ranges and are competitors to each other, their collaboration will bring the frozen vegetable food business to a higher level (https://www.rte.ie/news/business/2021/1208/1265462-strong-roots-mccain/).

The founder of SR has seen a market gap in the frozen food business as most of the companies focused on making profit, rather than creating sustainable food products for the consumers. The products started to fill the niche market and achieved a huge success shortly after the business started to operate. As agricultural sector has an enormous carbon footprint (CF), making the sourcing and manufacturing process as sustainable as possible put a lot of pressure to the company (https://fortune.com/2022/03/11/strong-roots-founder-samuel-dennigan-interview/).

A study found out in U.S., that the annual global food waste reached 1.6 tons recently. The most wasted were the fresh products by nearly 60% thrown to the bins annually. SR vastly contributes to fight against food waste, by incorporating it to each phase of the farm to freezer cycle. They treat and use rain water to wash the vegetables, biogas is generated by using the vegetable bi-products which provides energy for the manufacturing processes. Strong Roots received a title of B Corp Certification, which is awarded to companies who work for a more transparent, customer focused, high standard, sustainable standards. All SR products are non -

GMO, artificial ingredients free, 100% plant – based vegan products, ingredients are mostly either sourced from local farmers or grown locally by the company (https://www.prnewswire.com/news-releases/strong-roots-takes-on-the-global-food-waste-crisis-one-pound-at-a-time-301014481.html).

Image 7: Food product range offered by Strong Roots (https://fortune.com/2022/03/11/strong-roots-founder-samuel-dennigan-interview/).

3.2 Regular Beef Burger

Cattle farming in the U.S gives an enormous value to the economy with an approximated worth of 60 billion us dollars, based on 2016 research. Furthermore, the consumption of beef burger, as being one of the most sought-after meat products, reaches an overall 50 billion per year. The classic way of beef producing composed of a 6 to 8 months of period what the cow and the calf spend on pasture with an additional interval of backgrounding before the final stage of feedlot operation which keeps the cow and the calf on a high level of feeding. Corn, barley and wheat are the main food for the cows with other options like gluten and other grains which mainly available as a by-product of other industries such as a distillery. Once the cattle have reached the required weight of 63 percent of their live weight, they are being slaughtered for human consumption. Figure 9 summarises the beef burger process (Khan et al., 2019).

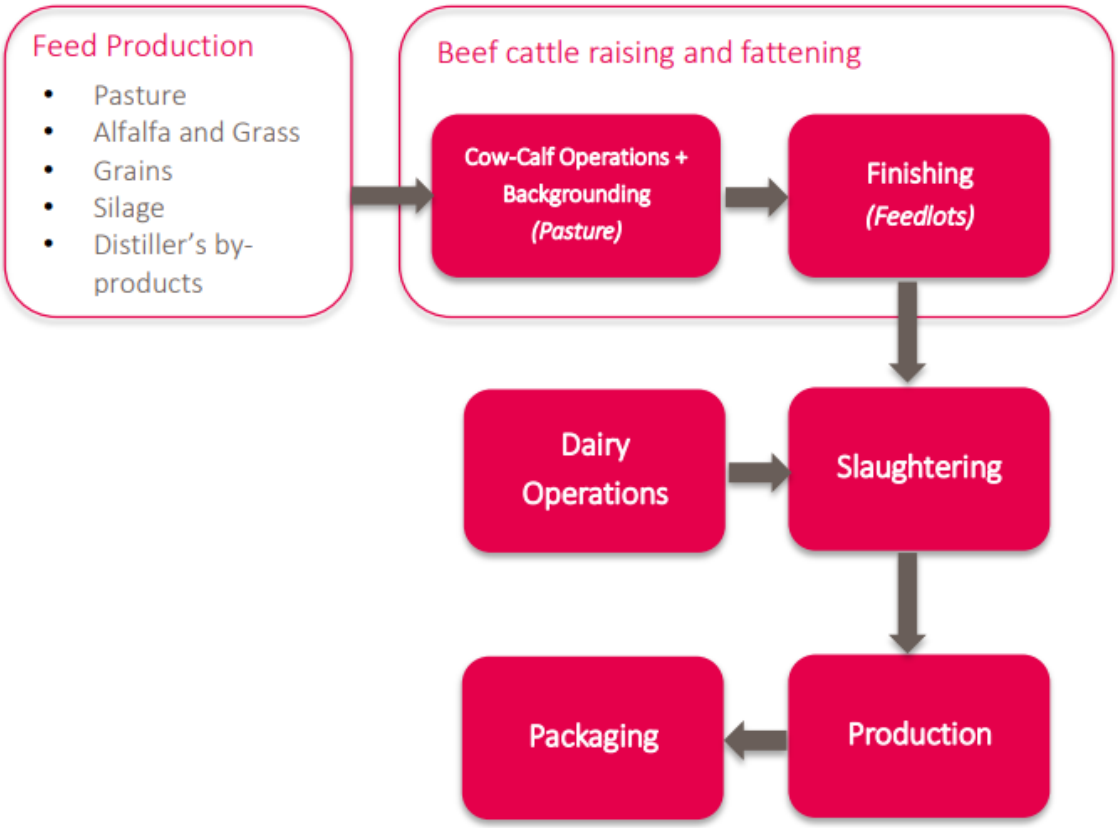


Figure 9: Manufacturing process flow of beef burger, raw material inputs & conveyance (Khan et al., 2019).

As per a 2016 report, the dairy business provided 26% of the consumed beef. The main sources of the beef have been eaten in the U.S, originates from dairy cattle, when they are no more useful for the dairy industry (Khan et al., 2019).

3.3 Nutritional Composition Comparison of Plant Based Burger and Meat Based Burger

The rise of flexitarianism has been a great accelerator of the growing interest towards plant - based substitutes and it's been resulted in a prominent increase in demand for these products. Flexitarianism relates to those individuals whom are originally meat eaters and find meat as a great source of nutrients, but their awareness of mindfulness about ethical and ecological views, sustainability has been risen, hence they're lowering their meat consumption. There have been several meat substitute products landed on the shelves recently due to the rapidly growing demand of vegan products, however these products may misinform and mislead the consumers

by their naming convention, as these products use the same names as the original products, i.e., burger, sausage, bacon, etc. The naming convention of the dairy products are regulated in the EU, but regulation of naming of the meat alternatives are yet to be controlled. For example, the word “burger” used on a plant - based product, can give a wrong indication for the buyer of the nutritional content of the item, as it may not representing the expected nutritional value of a “burger”. The flexitarian individuals are also looking to find these alternative vegan products as healthier, contain less saturated fats and cholesterol (de Marchi et al., 2021).

There has been a study conducted by de Marchi et al., (2021), which analysed the nutritional composition of the meat – based and plant – based burgers and compared them.

Colour of the food is one of the first impression a buyer perceives when it comes to buying a product, hence a proper, expected colour is extremely important as it’s may be a decider of the purchase. PH of the food is responsible for the pigments, which effects the colour of the meat, vegetables and fruits (de Marchi et al., 2021).

Table 13 depicts the level of PH and colour of the PB (plant – based) burger and the MB (meat - based) burger. The PH median of the PB burger is slightly higher (5.81) compared to the MB burger by cause of the larger level of alkalinity of the components. The existence of hemoglobin in meat products is known for giving the meat its red colour, hence most of the meat products are expected to be red in colour. Plants such as soy also contains some hemoglobin, called leghemoglobin but in a much lower content. This explains the difference in “a” and “b”, by being PB burger lesser colourful than the MB burger. There has been no significant difference in lightness, between the two types of burgers. PB burgers are often contain natural colourants like beet, to provide the desired “bloody” colour of the products (de Marchi et al., 2021).

Table 13: PH and colour investigation or raw MB and PB burger (pH: potential of hydrogen level, L: lightness, a: green – red colour, b: blue – yellow colour) (de Marchi et al., 2021).

	Meat-based burger		Plant-based burger		
Trait[2]	Median	95% $CI_{50\%}$	Median	95% $CI_{50\%}$	*p*
pH	5.48	5.28–5.70	5.81	5.58–7.29	0.038
L*	44.89	42.36–48.61	47.99	39.87–48.90	0.481
a*	19.82	16.95–20.94	16.83	15.60–17.45	0.032
b*	14.46	13.57–15.88	11.21	9.63–11.77	0.004

There have been some differences noticed in gross content of the raw product (Table 14). The observed significantly higher carbohydrate content in PB burgers (8.37%) as opposed to the MB burger (2.09%) is mainly due to their greater level of dietary fibre content (PB burger: 4.27%, MB burger: 0.74%). Fibre is essential for the digestive system and it's also been recommended to increase its intake for a healthier intestinal activity. The regularly mentioned protein level in both types of burgers is almost identical (MB burger: 17.96% & PB burger: 18.01). There have been slight or little differences reported in moisture, fat, fructose, starch and gross energy (de Marchi et al., 2021).

Table 14: Gross content and gross energy of the raw product (de Marchi et al., 2021).

Item	Meat-based burger		Plant-based burger		p
	Median	95% $CI_{50\%}$	Median	95% $CI_{50\%}$	
Moisture (%)	65.91	61.51-69.60	60.91	52.81-64.01	0.037
Ashes (%)	1.79	1.77-1.82	2.52	1.87-3.47	0.003
Protein (%)	17.96	15.89-18.75	18.01	13.30-18.43	0.514
- Collagen[2] (%)	2.49	1.37-2.83	-	-	-
Fat (%)	12.51	7.98-20.33	11.10	8.76-19.08	0.631
- Cholesterol (mg/100 g of the raw product)	50.60	48.81-54.26	3.98	3.88-4.55	0.003
Carbohydrates (%)	2.09	2.00-2.76	8.37	7.62-10.03	0.003
- Starch (%)	0.93	0.86-1.14	0.31	0.10-1.21	0.161
- Fructose (%)	0.022	0.019-0.055	0.013	0.010-0.056	0.571
- Total dietary fiber (%)	0.74	0.48-0.98	4.27	2.90-5.02	0.003
Gross energy (MJ/kg DM)	28.42	26.11-30.26	24.86	23.98-28.61	0.031
Gross energy (MJ/kg of the raw product)	9.69	7.94-12.19	9.41	8.92-13.50	1.00

[1]95% $CI_{50\%}$: median 95% confidence interval

[2]Collagen percentage was calculated as (Hydroxyproline × 8)/10^3

Nutritious foods contain several types of minerals which are known to support and maintain a good overall health level. In levels of the amplest minerals (Figure 10), calcium, potassium, magnesium, sodium, phosphorus showed a greater content in PB burger than in MB burger. Mainly, all other minerals showed close level of contents in both burgers (de Marchi et al., 2021).

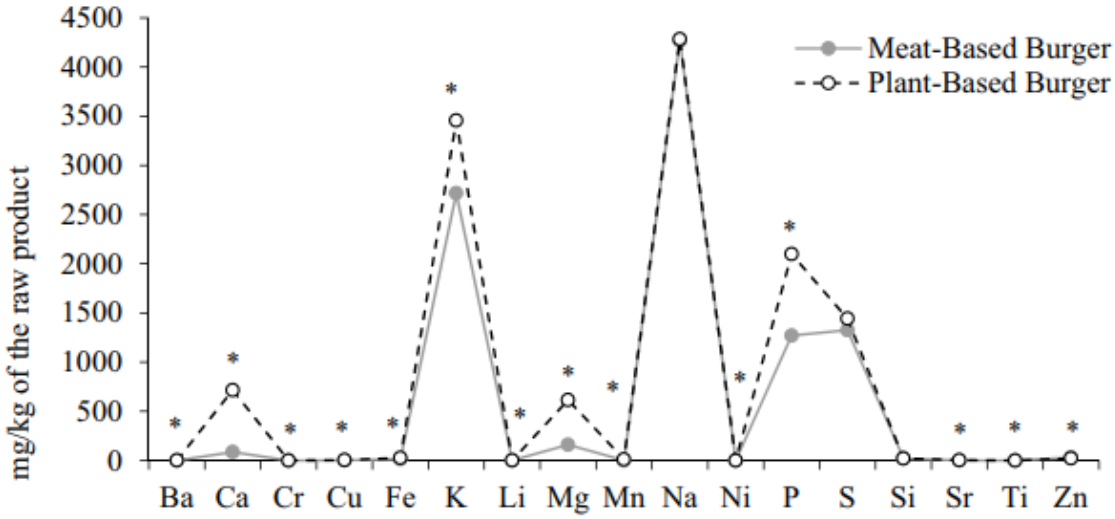


Figure 10: Level of mineral content in raw material (mg/kg) of MB and PB burgers. (Ba: Barium; Ca: Calcium; Cr: Chromium; Cu: Copper; Fe: Iron; K: Potassium; Li: Lithium; Mg: Magnesium; Mn: Manganese; Na: Sodium; Ni: Nickel; P: Phosphorus; S: Sulphur; Si: Silica; Sr: Strontium; Ti: Titanium; Zn: Zinc) (de Marchi et al., 2021).

In relation to fat content of both burgers, only a slight difference had been observed (PB burger: 11.10%, MB burger: 12.51%). The level of saturated fats (SFAs) showed a slightly higher level in PB burger (52.18% versus 48.8%). Monounsaturated fatty acids (MUFAs) resulted in lower content in PB burger (32.29%) than in MB burger (45.66%). A greater difference observed in both n-3 fatty acids and in n-6 fatty acids. Both Omega 3 (n-3) and Omega 6 (n-6) are essential for a healthy human body, but when taken excessively, and Omega 6 (Linoleic Acid) is not balanced with Omega 3 (Linolenic Acid), it can cause blood clothing, inflammation, and other detrimental health effects. A greater level of Omega 6 content was anticipated (Table 15) in PB burger (15.66%) compared to the MB burger (2.65%), due to the higher level of vegetable oil (i.e., sunflower oil) content in PB products. Regardless of the lower level of trans fatty acids

in both burgers, the higher amount in MB burgers (0.125%) is mainly due to hydrogenated fats and animal derived fats, hence the lower amount found in PB burger (0.079%) (de Marchi et al., 2021).

Table 15: Levels of fatty acid (FA) contents in raw material (% of total FAs) (de Marchi et al., 2021).

	Meat-based burger		Plant-based burger		
Group[2]	Median	95% $CI_{50\%}$	Median	95% $CI_{50\%}$	*p*
SFAs	48.8	45.63–53.38	52.18	40.49–61.93	0.631
MUFAs	45.66	38.20–50.64	32.29	16.11–41.34	0.026
PUFAs	4.92	3.90–10.53	20.12	15.42–22.98	0.003
n-3	0.64	0.40–0.89	3.56	0.26–4.04	0.514
n-6	3.91	3.19–8.44	15.76	11.72–22.32	0.003
n-6/n-3 ratio	7.26	5.26–9.47	3.51	3.22–84.96	0.514
CLA	0.55	0.45–0.79	0.044	0.035–0.054	0.003
cis-FAs	2.82	2.35–2.46	0.93	0.32–1.85	0.004
trans-FAs	0.125	0.057–0.179	0.079	0.004–0.099	0.037
SCFAs	0.18	0.14–0.40	7.24	5.32–8.91	0.003
MCFAs	35.92	35.12–37.59	41.90	32.19–49.70	0.186
LCFAs	64.47	63.45–65.06	50.90	41.40–62.45	0.012

$CI_{50\%}$: median 95% confidence interval. [2]SFAs: saturated FAs; MUFAs: monounsaturated FAs; PUFAs: polyunsaturated FAs; CLA: conjugated linoleic acid; n-3: Omega-3 FAs; n-6: Omega-6 FAs; SCFAs: short-chain FAs; MCFAs: medium-chain FAs; LCFAs: long-chain FAs; *cis*-FAs: *cis* stereoisomers of FAs; *trans*-FAs: *trans* stereoisomers of FAs excluding CLA.

Out of the three short- (SCFAs), medium- (MCFAs) and long chain fatty acids, the highest level observed was the long chain fatty acid (LCFAs) in both categories (Table 16). Both C12:0 (lauric) and C14:0 (myristic) derived from coconut oils, hence the much higher level observed in PB burger (lauric in PB burger: 23.83% and in MB burger: 0.16% and myristic in PB burger: 9.60 compared to in MB burger: 3.13%). On the contrary, C16:0 (palmitic) in MB burger presented in 26.33%, compared to the PB burger (7.72%), and C18:0 (stearic) appeared in 15.41% in MB burger, as opposed to the percentage of 2.37 in PB burger. Both fatty acids are mainly derived from animal flash (Table 16) (de Marchi et al., 2021).

Table 16: Percentage level of the amplest fatty acids in total fatty acids in raw PB and MB burgers (de Marchi et al., 2021).

Fatty acid	Meat-based burger		Plant-based burger		*p*
	Median	95% $CI_{50\%}$	Median	95% $CI_{50\%}$	
C12:0	0.16	0.09–0.37	23.83	17.65–29.04	0.010
C14:0	3.13	3.07–3.36	9.60	7.23–11.36	0.003
C16:0	26.33	25.83–26.51	7.72	6.97–9.01	0.003
C18:0	15.41	12.92–19.29	2.37	2.23–3.06	0.003
C18:1n9	36.13	30.62–39.97	29.88	15.40–38.35	0.119
C18:2n6	2.65	2.04–6.46	15.66	11.64–22.19	0.003

In conclusion of the nutrient composition of both the burgers, the outcome of the analysis has indicated that plant- based meat substitutes can offer a similar or even better nutrient profile, particularly in level of protein, fatty acids, fibre, minerals, to the homonymous version. As a result of the report, PB burger can offer an adequate alternative for the flexitarian individuals to achieve their goal to consume nutrient rich healthy food, while being more sustainable and less harmful for the animals (de Marchi et al., 2021).

Chapter 4 – Methods and Materials

4.1 Methods

This part of the thesis layouts the methods used to express how a vegan diet, particularly a meat substitute made of only plants be of benefit in health effects and environmental sustainability. The research method used was based on a desk research study, used peer reviewed studies and articles for data gathering and websites for company information.

4.2 Search Strategy

The electronic database used for searching articles was DOAJ (Directory of Open Access Journals). The search was mainly in relation to vegan, plant – based diets, omnivorous diet, environment, health effects. The search terms included were “vegan”, “plant - based diet”, “meat alternatives”, “meat consumption”, “omnivorous diet”, “environmental impacts”, “green - house gas emission”, “climate change”, “cardiovascular diseases”, “colorectal cancer”, “cardiovascular mortality” and their related synonyms.

All references were imported into Mendeley Reference Manager Program for citing. Duplications had been removed.

Beside electronic database, internet searches took place to find relevant information for certain parts of the study. This was only used to gather data about companies, i.e., Impossible Foods, Strong Roots and Plant–It (i.e., www.plantit.com, www.impossiblefoods.com).

Only original articles in the English language were included in the dissertation.

4.3 Data Inclusions

The data used in the thesis has been pulled from recent studies, generally from the past 5 years. Any data has been used from older publications were only took in consideration where data was still applicable and modern and no more novel data had been accorded. The oldest issued

publication used was from 2014 (1 study). 3 publications were from 2015, 1 from 2016, 2 from 2017, 2 from 2018, 3 from 2019, 2 from 2020, 9 from 2021 and 6 from 2022.

4.4 Data Exclusions

Data obtained from non - peer reviewed articles has been excluded from the study. Only articles used to find information about the relevant food businesses were not peer reviewed.

Chapter 5 – Discussion

5.1. Impossible Burger & Regular Beef Burger Production Review

Worldwide food production by animal agriculture and farming is a tremendous contributor to global warming, causing detrimental ecological effects. Life cycle assessment (LCA) is a method, which became widely used in the last 10 years to quantify these detrimental effects and to assess the escalation of food manufacturing (Figure 11). The analysis of a food product contains data from different fields, agricultural main product manufacturing, production, conveyance, waste management, at a country or global level (Bengoa Xavier et al., 2015).

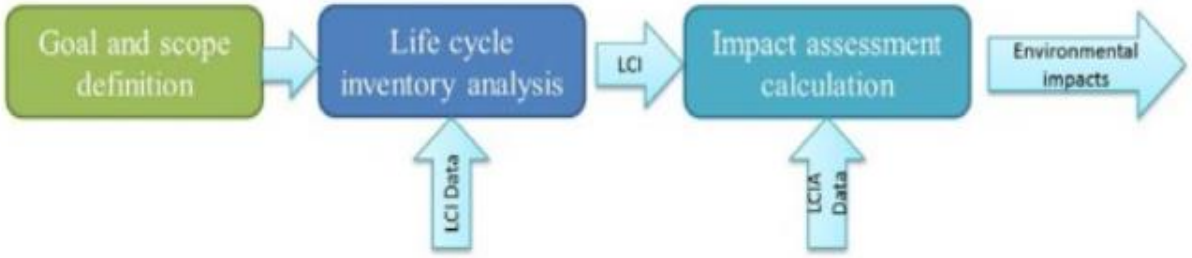


Figure 11: Four phases of LCA (https://www.sciencedirect.com/topics/engineering/cradle-to-gate-assessment).

The world is fronting one of its biggest challenges by nourishing 10 billion people by 2050 with the key task of protecting our planet for the future at the same time. In order to keep up with the overwhelming demand, an estimated 70% of overall food production rise would be required in comparison to a decade ago. This would involve a massive increase in produce of grains to 3 billion tons and meat to 470 million tons. While the world is looking to increase the food production in every front, roughly 25% of GHG emission is derived from animal farming and food producing, detrimentally impacting the fresh and seawaters, causing soil depletion, and using almost half of the total croplands. The overall goal is to maintain and even lower the detrimental environmental impacts, while meeting the food production demand. Questions have been risen, which are yet to be answered. What will people consume and what will be the way of food production? The transformation towards plant – based food production and consumption opens the doors to a more environment friendly and sustainable way of achieving these goals and demands (Khan et al., 2019).

5.1.1 Objective

The objective of this section is to review Impossible Foods with an in-depth analysis about the environment impact comparison, between their key product Impossible Burger (IB) and a regular beef burger in the U.S. Specifically focusing on whether Impossible Burger gives any environmental benefits compared to the conventional version, assessing land usage, water intake, water pollution, global warming capability, particularly realizing and understanding the main reasons and discrepancies of the impacts for both types of burgers. Impossible Foods created their unique, 100% vegan plant-based product The Impossible Burger. The methodology of this comparison assessment utilizes the life cycle assessment (LCA) method under the guideline of ISO 14044. The comparison also reviews the culinary and nutritional point of view of the two types of burgers (Khan et al., 2019).

5.1.2 Comparison Bases, System Depiction, Data Sources

The definition of the comparison framework references the evaluation of the functional parameter of the life cycle assessment. There is a wide variety of measurements, which the comparison can be based on. The selected framework for this analysis is the so-called cradle to gate evaluation, which compares 1 kg of regular, raw, boneless beef from U.S, to 1 kg of raw Impossible Burger product. The cradle to gate framework assesses the four main areas of ecological impacts: water usage, land use, climate change and aquatic eutrophication. No other functional measurements like, sensory analysis, taste or any other are measured in this context (Khan et al., 2019).

The cradle to gate framework depicts the production process flow up to the phase where the product will be in use (Figure 12) (https://www.sciencedirect.com/topics/engineering/cradle-to-gate-analysis).

Figure 12: Cradle to gate process flow (https://www.sciencedirect.com/topics/engineering/cradle-to-gate-assessment).

5.1.2.1 Impossible Burger Production

A typical agronomics dataset was the primary source for all data captured. In the absence of the primary data, country specific, region specific or if none of these were available then data based on global inventories were utilized. The necessary data for the Impossible Burger life cycle assessment were obtained by the company. Data was available for heme and burger production, ingredients, energy use, packaging and transportation. Most of the ingredients were sourced locally with the exception of coconut oil which was produced and transported from the Philippines. The average road transportation by truck for the main ingredients were assumed to be 786 km. The Impossible Food products are made in a plantation in California. The assessment administers the electricity usage over a course of year of the production (Table 17). The majority of the electricity used is derived from nuclear plantation and from natural gas. Renewable energy is sourced from solar (11.5 kWh), wind (7.75 kWh) and biomass & waste (4.25 kWh). The packaging of 1kg of IB at factory level consist of 1.6 g of paper for the patty, total of 2.7 g of plastic film and 10g of corrugated cardboard (Table 18) (Khan et al., 2019).

Table 17: source of 100 kWh electricity (Khan et al., 2019).

PRODUCT	100 kWh of PG&E Electricity Production	
Input	Quantity	Unit
Solar	11.5	kWh
Wind	7.75	kWh
Biomass and Waste	4.25	kWh
Hydroelectricity, Run-off	2	kWh
Natural Gas	21.5	kWh
Nuclear	23.75	kWh
Hydroelectricity, reservoir	11	kWh

Table 18: Packaging material breakdown (Khan et al., 2019).

PRODUCT	1 kg of Packaged IF Burger, at factory	
Input	Quantity	Unit
Impossible Food Burger	1	kg
Paper, patty paper	1.6	g
Plastic Film	2.3	g
Corrugated cardboard	10	g
Outputs	Quantity	Unit
Plastic Film	0.4	g

5.1.2.2 Regular Beef Burger Production

The data used for cattle farming in the U.S in this review is derived from the U.S. Meat Animal Research Centre (USMARC). The data provides information about animal feed, crop and management operation of the cattle. The feeding cycle of the cattle starts with 6 months on crop, followed by a 3 month of backgrounding and finished in a feedlot for 7 months. The cattle initially consumed grain from the distillers and hay and then mainly grain based. The cattle herd used in this analysis consist of cows (5498), bulls (285), calves (5050), heifers (1180). Initially in the operation, 3724 cattle with an average weight of 581 kg and an additional 1100 cows and 80 bulls with an average weight between 650 kg to 900 kg were sent to a

slaughterhouse, resulting an overall live weight of 3213 tons. Table 19 reports the overall feed intake to produce 3123 ton of cattle. Altogether, 23,808 ton of pasture required to feed the cattle, including 4833 ton of alfalfa and hay, 2416 ton of corn silage, 104 ton of high moisture corn, 56 ton of corn grain and 45 ton of grains form distilleries. Table 20 reports the overall energy usage for 3123 ton of beef production. This includes 1,070,441 kWh of electricity, 16,571,820 MJ of fuel, 11,161,800 MJ of natural gas and 371,495 m3 of potable water. These additional figures were given to support the environmental impact assessment. Distance of 100km were calculated for feed transportation, locally grown in the U.S. (Khan et al., 2019).

Table 19: Feed intake of Cow-calf and backgrounding for 3123 ton of beef cattle production (Khan et al., 2019).

	Quantity (ton)	
Feed	Cow-calf + Backgrounding	Feedlot
Pasture	23,808	0
Alfalfa and grass hay	4,833	707
Corn silage	2,416	2,507
High moisture corn	104	2,718
Corn grain	56	1,596
Distillers grain	45	1,623

Table 20: Energy (Electricity, Fuel, Gas, Water) usage for 3123 ton of beef production (Khan et al., 2019).

Input	Quantity	Unit
Electricity	1,070,441	kWh
Fuel	16,571,820	MJ
Natural gas	11,161,800	MJ
Water, for drinking	371,495	m^3

For the production of 1 kg of live weight, different components of emission were used. The manure left by the cattle remains on the pasture during the activity of cow-calf backgrounding, and most of the manure generated on feedlots (95%) is laid out on crop fields (Table 21). The highest figure is the methane (CH4) enteric fermentation with 360 g/kg per live weight (Khan et al., 2019).

Table 21: Element of emissions for manure control and emissions of enteric for cattle per element of live weight (CH4: Methane, NH3-N: Nitrogen, NO2: Nitrogen Dioxide, N2O: Nitrous Oxide) (Khan et al., 2019).

Input	Quantity (g/kg LW)
CH_4, enteric fermentation	360
CH_4, manure management	4.4
NH_3-N, manure management	2.1
NO_2, manure management	4
N_2O, manure management	2.9
Phosphorus runoff, manure management	0.25

In proportion, 1 kg of beef cattle is derived from roughly 7% of dairy cows (70 g) and 15% of male calves (150 g), which gives a total of 22% to beef from dairy farms (220 g). The majority of the beef cattle comes from beef farms (780 g). The proposed distance of transportation between the dairy farm and the slaughterhouse was 200 km (Table 22).

Table 22: Proportion of Slaughtering of a beef cattle (Khan et al., 2019).

PRODUCT	1 kg of slaughtered beef cattle	
Input	Quantity	Unit
Beef, cattle, for slaughter, at beef farm	780	g
Culled dairy cows	70	g
Male calves	150	g
Slaughtering activities	1	kg
Cattle transportation	0.2	tkm

Ecological designation was factored in to determine impact rates for fresh meat and for co-products for 1 kg of beef product (Table 23). Almost half is made from fresh meat (460 g) and the remainder derives from co-products, such as bones (80 g), fat (70 g), offal (30 g), blood (30g), other by product of slaughtering (30 g), hides & skins (70 g) and other materials and waste (230 g). Fresh meat has the highest ecological impact on the environment by 93.2% out of 100%. Hides & skins and fat have 3.78% and 1.42% contribution to environmental impacts (Khan et al., 2019).

Table 23: Products of beef slaughter and economic allocation factors (Khan et al., 2019).

Product	Quantity (g)	Economic allocation factor (%)
Beef, fresh meat	460	93.2
Beef, food grade offal	30	0.61
Beef, food grade bones	80	0.7
Beef, food grade fat	70	1.42
Beef, food grade blood	30	0.32
Beef, cat. 3 slaughter by-products	30	0.01
Beef, hides and skins	70	3.78
Beef, cat. 1 and 2 materials and waste	230	0

5.2 Impact Evaluation, Contribution and Uncertainty Analysis

Life cycle assessment approach had been selected in this study to evaluate the ecological impacts. The impact evaluation determines and merges the material & energy flow, and the impact of each product into and out. There are multiple categories (15+) to assess the affect, which are being accumulated in to end groups for the outcome. This study analyses the four main impact groups (Figure 13). The particular four are, aquatic eutrophication, climate change, land occupation and freshwater usage. All four measurements are widely known and used for impact assessment, particularly in animal farming and agricultural sectors. The main goal was to focus on the four most important impacts when comparing an animal and plant derived food product with each other from an environmental impact point of view (Khan et al., 2019).

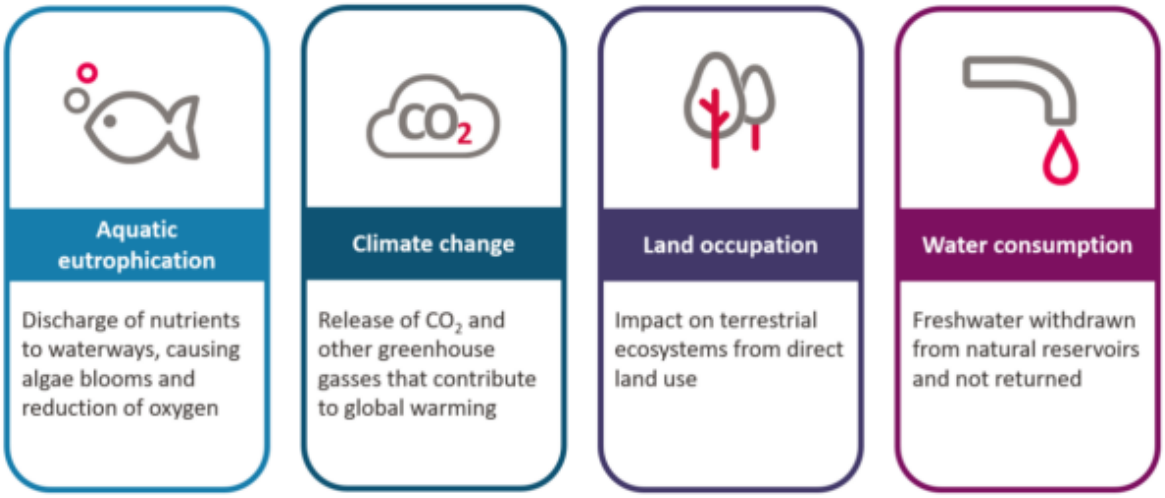


Figure 13: Description of the 4 main ecological impact factors this study assesses (Khan et al., 2019).

1. Aquatic Eutrophication

It determines the process, when excessive amounts of nutrients are added to the marine ecological system. These can be phosphorus and nitrogen which are mainly derived from waste water plants and from agricultural drainage systems. The effect of eutrophication which is also called as over nutrification, generates biomass increase, i.e., algae blooms, which negatively impacts the aquatic life due to the bloom die off process which takes oxygen away from the waters. Kg of PO4 is commonly used as a measurement of nutrification (Khan et al., 2019).

2. Global Warming Potential

The Earth is getting warmed up by greenhouse gases by energy absorptions and by a slower speed of energy escape to the space. This causes an insulation layer on the planet. The level of impact depends on the type of gases, their lifetime (appearance in time in the atmosphere) and their energy absorption power. The global warming potential (GWP) was created for differentiating the global warming impact of the different type of gases, particularly measuring how much energy of 1 ton of CO2 will be absorbed over a certain amount of time. When the level of GWP is more, the higher the impact is (https://www.epa.gov/ghgemissions/understanding-global-warming-potentials).

GWP is usually demonstrated in measurements (g / kg / tons) of carbon dioxide (CO2) equivalents (Khan et al., 2019).

CO2 has 1 GWP as a reference. CO2 remains in the atmosphere for thousands of years. CH4 (methane) has a GWP of approximately 30. Methane emitted today remains in the atmosphere for roughly 10 years, which is significantly lesser than the CO2, however methane absorbs more energy than carbon dioxide. N2O (nitrous oxide) has a GWP of 273. Today's emission of N2O lasts for 100 years+ in the atmosphere. All measurements based on a 100 years life cycle (https://www.epa.gov/ghgemissions/understanding-global-warming-potentials).

3. Land Occupation

Land usage has a crucial role of GHG emissions in ecological cycle. Land occupation activities can emit or remove GHGs from the atmosphere. The usage of lands can play an important part of climate change mitigation, avoiding deforestation and ocean pollution, keeping the marine ecosystem at a sustainable level. The occupation of lands is directly connected to food production, which is one of the biggest challenge for the near future (https://unfccc.int/topics/land-use/the-big-picture/introduction-to-land-use#:~:text=Land%20plays%20an%20important%20role,greenhouse%20gases%20from%20the%20atmosphere).

4. Water Consumption

Water consumption refers to all amounts of water used by the product during its life cycle. This volume of water includes potable water taken from freshwater pools, rainwater reached lakes and ponds, potable water, water used for manufacturing, cooling water and excludes seawater and any amount returned to the water systems (Khan et al., 2019).

It is important to declare, that LCA generally don't illustrates the actual environmental impacts that occurred, it illustrates the potentially estimated ecological impacts that can appear. The LCA result does not involve other human actions like noise pollution as an example (Khan et al., 2019).

Contribution analysis determines the volume of each process by their proportion of total impact of the Impossible Burger. Generally, lower impacted processes contribute to lesser quality of

data, and the greater affected procedures on this analysis is contributed to a higher quality of data (Khan et al., 2019).

Due to the variety of different data sets, uncertainty analysis is to be noted when assessing an LCA. Sources of data are generally based on time frame, completeness, accuracy, technology used and differences, geographical area and differences, representativeness, comprehensiveness, validity (Khan et al., 2019).

When data is used as a main source of information, accuracy is the most critical standard to meet. An accurate data is reliable, error free and can be used as a main source of information (https://dataladder.com/what-is-data-accuracy/).

5.3 Environmental Impact Comparison of Impossible Burger & Regular Beef Burger

The result of the assessment of the four lead impact categories between the Impossible Burger and the regular beef burger shows, that the impacts of the produce of the IB is much lower than the production of a regular beef burger. The beef cattle raising phase is clearly the indicator of the significantly bigger environmental impact figures (between 41% and 93%) of the beef burger (Table 24) (Khan et al., 2019).

Table 24: LCA comparison result in the 4 leading impact categories between 1kg of IB and 1 kg of traditional beef burger (Khan et al., 2019).

Impact Category	Unit	Impossible Burger®	Beef Burger	Difference %
Aquatic eutrophication potential	g PO4-eq	1.28 *(2.3-9.7)*	15.1 *(14.3-60.6)*	-92%
Global warming potential	kg CO2-eq	3.5 *(3.1-4.0)*	30.6 *(25.3-37.5)*	-89%
Land occupation*	m2.y	2.5 *(1.6-3.7)*	62.0 *(37.0-102.5)*	-96%
Water consumption	l	106.8 *(56.9-203.3)*	850.1 *(617.9-1238.1)*	-87%

** Land occupation is at the inventory level.*

The biggest difference resulted in land usage, whereas the production of 1 kg of beef burger required 62 m2 per year of land occupation, compared to 1 kg of IB production, which required

2.5 m2 per year of land only. This gives a 96% ratio difference between the two products. The main part of the difference, roughly 90% comes from the need of pasture for the cattle, the remainder mostly comes from agricultural production (yearly 6.4 m2 for regular beef burger compared to 2.3 m2 for IB). The comparison result of aquatic nutrification gives the second biggest savings potential by the IB over the traditional meat burger by its 92% ratio. 15.1g phosphate equivalent for beef burger, over 1.28 g phosphate equivalent for IB. No phosphate needed for IB production, hence the elimination of it makes the difference, compared to the beef burger, where phosphate is emitted during the cattle activities, manure, feeding and fertilizing operations (Khan et al., 2019).

The third and the fourth potential savings are the potential of global warming affects and water consumption. 30.6 kg carbon dioxide was emitted during the production of the beef burger compared to a 3.5 kg of CO2 emissions for IB production (89% ratio). The 26.3 kg of CO2 emission difference stems from enteric fermentation and manure operations used for cattle, 11% is responsible for feed production and logistics and the remainder from slaughtering. These are not relevant for IB production. The production of 1kg of beef burger required 850.1 litres of water as opposed to 1 kg of IB, which needed 106.8 litres of water to produce which sums up a 743 litres of water difference (87% ratio). The production of maize for beef cattle is roughly responsible for 82% of water intake difference, which is not relevant for the production of IB. Figure 14 depicts the relative result differences between the LCA of the 2 burger types by highlighting 4 indicators, results normalized to BB production impacts (Khan et al., 2019).

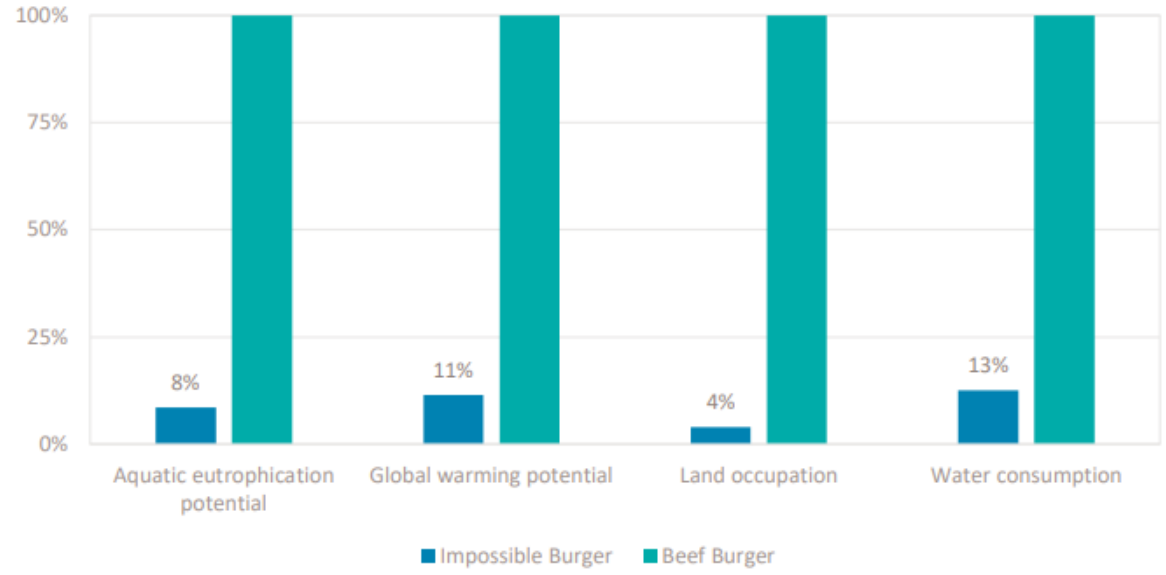


Figure 14: LCA comparison differences of BB and IB, with figures normalized to BB impacts by each four categories used (Khan et al., 2019).

5.3.1 Detailed Environmental Impact Results for the Impossible Burger

The Impossible Burger's ingredients mix manufacturing and the whole burger production are the two main stages of lifecycle which have the most important environmental impact, as it can be seen in Figure 15. The packaging phase as an impact factor can be nearly neglected as it only adds maximum 1-2 % impact contribution. Electricity usage is the biggest contributor during the production stage as well as the requirement of the refrigeration of the products, which emits nitrogen and carbon dioxide. 21% of overall global warming potential is due to the electricity usage. The production and usage of fossil fuel were due to 14% of overall water usage and 15% of overall water nutrification impacts. The contribution of these to land usage is just 0.1%. 0.19kg CO2 equivalent is caused by the emissions of refrigerants which generates a 5% total GWP affect. The process of the IB mix contains the making of heme, fats and other parts, which give between 42% to 82% of all affects to the life phases of the Impossible Burger (Khan et al., 2019).

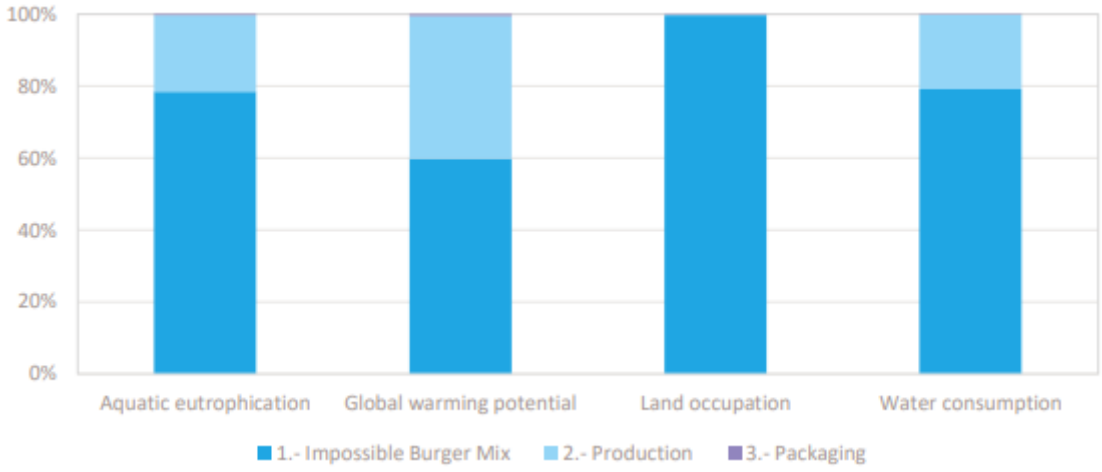


Figure 15: Distribution of Impossible Burger's LCA affect amid burger mix, land usage and packaging phases (Khan et al., 2019).

The breakdown of total IB impacts of each four impact categories can be seen in Figure 16. As mentioned, the produce of IB mix is the biggest contributor to the four main impact categories and across the three life cycle stages. 84.49 litres of water usage out of the total 106.82 litres, 2.46 m2 of land occupation out of the total 2.5 m2 and 1.0 g of phosphate equivalent emission out of the total 1.28 g (Khan et al., 2019).

Impact Category	Unit	Total	1.- Impossible Burger® Mix	2.- Production	3.- Packaging
Aquatic eutrophication potential	g PO4-eq	1.28	1.00	0.27	<0.1
Global warming potential	kg CO2-eq	3.50	2.09	1.38	0.02
Land occupation*	m2.y	2.5	2.46	0.01	<0.1
Water consumption	l	106.82	84.49	22.13	0.19

** Land occupation is at the inventory level.*

Figure 16: Life cycle impact review of 1 kg of IB during the series of life stages (Khan et al., 2019).

5.3.2 Ingredient Impact Analysis of Impossible Burger

Potato protein and coconut oil are mostly among the first and second position of the ranking of the ingredient contribution to each four impact categories. In the impact category of potential aquatic eutrophication, the first is potato protein, the second is coconut oil and the third is leghemoglobin protein. Leghemoglobin protein is the biggest contributor in the impact category of GWP, followed by potato protein and coconut oil. In the category of land occupation, the first is coconut oil, the second is soy protein and the third is sunflower oil. In the category of water usage, the first is potato protein, the second is coconut oil and the third is leghemoglobin protein (Table 25) (Khan et al., 2019).

It's been estimated that, 54% of total Impossible Burger water consumption comes from the production of potato protein, particularly the use of irrigation, which results in 62 litres of water usage. It accounts for 14% of total land occupation. As a result of phosphorus leakage from fertilizers, potato protein production accounts for 30% of total aquatic nutrification and to 9% of GWP affects. In regards to coconut and sunflower oil, the phase of refine takes 8.5 litres of water and they are also significantly contributing to land use, along with soy bean protein production (Khan et al., 2019).

Table 25: Ranking of IB ingredients of their impact potential across the four main impact categories (Khan et al., 2019).

Aquatic eutrophication potential	Global warming potential	Land Occupation	Water consumption
Potato protein	LegH protein	Coconut oil	**Potato protein**
Coconut oil	Potato protein	Soy protein	Coconut oil
LegH protein	Coconut oil	Sunflower oil	LegH protein
Sunflower oil	Flavor mix	Potato protein	Flavor mix
Soy protein	Sunflower oil	LegH protein	Soy protein
Flavor mix	Soy protein	Flavor mix	Sunflower oil

As a conclusion of the comparison of the Impossible Burger and a traditional beef burger, the main aim was to examine whether the plant based IB has a potential lesser environmental impact than the meat derived beef burger, and if so, then to what level. The most important finding of the evaluation was, that when the consumer in U.S, as this comparison study was conducted in the U.S replaces 1 kg of beef burger with 1 kg of plant - based, vegan Impossible burger, the environmental impact across all four impact categories (aquatic eutrophication possibility, global warming potential, land and water usage) reduces by 87% to 96%. Raising beef cattle for feeding humans require much more energy, land, water and way more heavily impacting the environment than those crops would directly be used for plant food for humans. This comparison review offers an option for the consumers to review their meat intake impacts and shows an alternative substitute product for a more sustainable way of food consumption (Khan et al., 2019).

5.4 Methods of Encouraging Consumers to Reduce Their Red Meat Intake

As it's been stated in many channels, reducing meat intake, particularly red meat is decisive for the future, in order to mitigate the global warming effects and prevent more serious illnesses in the future. The EAT Lancet commission in 2019 set a strategical future plan to assist and support one of the biggest environmental challenges nowadays. The Cancer Society in the United States has been working on this challenge to discourage the red meat intake of the people of America, and encouraging them at the same time to increase their poultry, fish and plant - based protein source intake, over red meat sources. Red meat substitution with fruits,

vegetables, plant alternatives, nut, legumes will result a lower risk of stroke and colorectal cancer development, type II diabetes and coronary heart disease and will also result a healthier balanced lifestyle (Wistar et al., 2022).

5.4.1 Addressing Environmental Impact Messages

One of another challenge beyond discouraging people to consume less red meat, which is yet to be answered is to establish practical and successful action plan for red meat intake mitigation. Communicating with consumers via messages has been considered as a useful way to deliver messages to encourage people to quit smoking, responsible drinking or sugar consumption. Environment and sustainability themed messages might further encourage the public, especially the younger generation, to be aware of their red meat consumption, climate change threats and the rise of global warming. The main challenge is to establish a well framed, information based effective messages, which can encourage the people to reduce their red meat intake and stresses the potential health and ecological threats caused by. Based on previous surveys and studies, wordings which were framed negatively founded to be more efficient, than their positively framed versions, i.e., not recycling the waste can further damage the environment, versus recycling the waste can support the environment. This is mainly due to psychology of being afraid of losses and negative impacts. However, there have been studies conducted based on both methods and showed different results. Either negatively or positively framed messages were selected, both found effective to support their key message. Framing the given topic, i.e., climate change as an ecological hazard, ethical matter or possibility for economic growth, made different reactions and engagement towards supporting the mitigation of climate change (Wistar et al., 2022).

Selecting the target group which will result in a satisfied outcome when conducting a survey is unknown. Based on previous studies, partakers from younger generation, females and people whom are generally consuming less meat than average from upper income countries, are more open to communication about environmental impacts and health issues caused by high red meat intake and encouragement of lowering its intake (Wistar et al., 2022).

There has been an experimental study conducted in the United States, involving 1078 (n) participants, where the effectiveness of the messages was analysed. The run of the 7 online messages addressed the mitigation of red meat intake at its reduction level or at its worst level

and compared and rated which message framing was more effective of encouraging people purchasing lesser beef products (Table 26). The messages stressed the negative ecological harms, i.e., deforestation, green - house gas emission, freshwater shortages, soil depletion, carbon footprint (Wistar et al., 2022).

Table 26: The text messages tested on 1078 U.S partaker (Wistar et al., 2022).

Frame 1: Worsening of Environmental Harms	Frame 2: Reduction of Environmental Harms
Buying beef can . . .	Buying less beef can . . .
increase your carbon footprint	reduce your carbon footprint
increase greenhouse gas emissions	reduce greenhouse gas emissions
contribute to water shortages	reduce water shortages
hurt the environment	help the environment
worsen climate change	help mitigate climate change
contribute to biodiversity loss	reduce biodiversity loss
contribute to deforestation	reduce deforestation

The experiment took place on an online platform where participants received questions about their sugar sweetened beverage (SSB) warning and consumption, then answered a question about their red meat intake frequency which was followed by a series of seven messages about environmental harms and impacts. Participants responded to each of the seven messages by answering how much it discouraged then to purchase beef in the future. The questions were framed in a way of how often do they buy beef and the answers included never, once a certain time period, i.e., day, week, month, etc. The message emphasized discouragement, was asking how much each impact factor disappoint the people to purchase beef. Answers ranged from not at all to great deal. PME was used as a measurement for this experiment. It is commonly used for testing in health associated communication (Wistar et al., 2022).

The demographic attributes can be seen in Table 27. The categorization of the sociodemographic characteristics grouped by average age, education level (more than high school or less), income level (less than $25K, $25K – $50K, $50K - $75K, $75K - $100K and above $100K), ethnicity (Latino, non - Latino), gender (male, female, transgender), frequency of beef consumption (less or more than once a week) (Wistar et al., 2022).

Table 27: Statistical categorization of the partakers of the online study (n=1078) by beef consumption, ethnicity, sociodemographic, language, income level (Wistar et al., 2022).

Age * (Years), Mean and SD	*n* or Mean	% or SD
	35.3	7.4
Education level †, *n* and %		
High school diploma ‡ or less	512	47.5
4 year college degree or more	566	52.5
Income level, *n* and %		
Less than $25,000	213	19.8
$25,000 to $49,999	288	26.7
$50,000 to $74,999	202	18.7
$75,000 to $99,999	157	14.6
$100,000 or more	218	20.2
Latino ethnicity, *n* and %		
Non-Latino	564	52.3
Latino	514	47.7
Gender, *n* and %		
Male	445	41.3
Female	628	58.3
Transgender	5	0.5
Beef consumption †, *n* and %		
Less than once a week	377	34.9
Once a week or more	701	65.0
Survey language, *n* and %		
English	924	85.7
Spanish	154	14.3

The average age of the partakers was 35.3 years, less than half of them were male (41.3%), 58.3% female and 0.5% transgender. Almost half and half regarding having a higher education (566) than high school or not (512), 514 were Latino and 564 non – Latino. Regarding beef consumption, 377 of them were consuming beef less than once a week, while 701 them were eating beef more than once a week (Wistar et al., 2022).

Figure 17 depicts the chart for both framed messages. The mean result of the reduction framed messages was 2.80, and for the worsening framed messages was 2.89. The difference is barely notable, however the questions composed to stress the worsening of harms, made a bigger effect across all seven topics (Wistar et al., 2022).

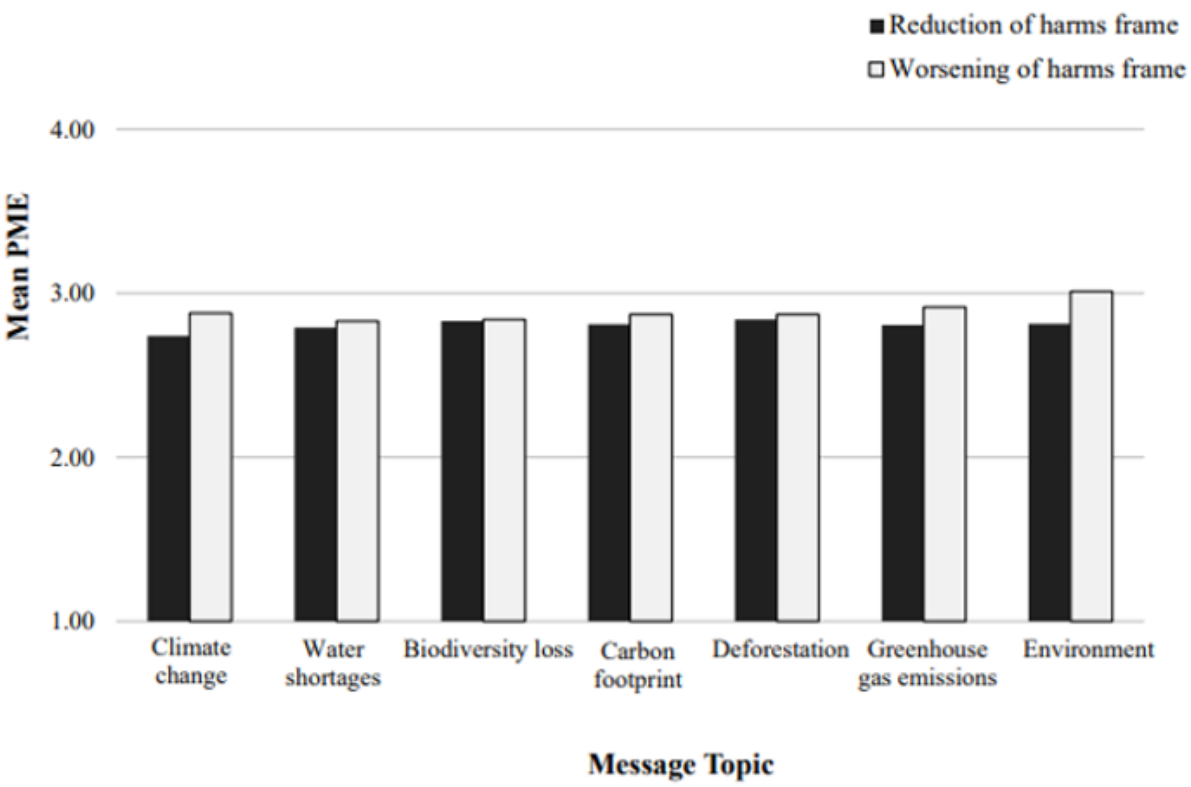


Figure 17: Understanding of the effectiveness of both messages by all seven impact topics and framing methods (Wistar et al., 2022)

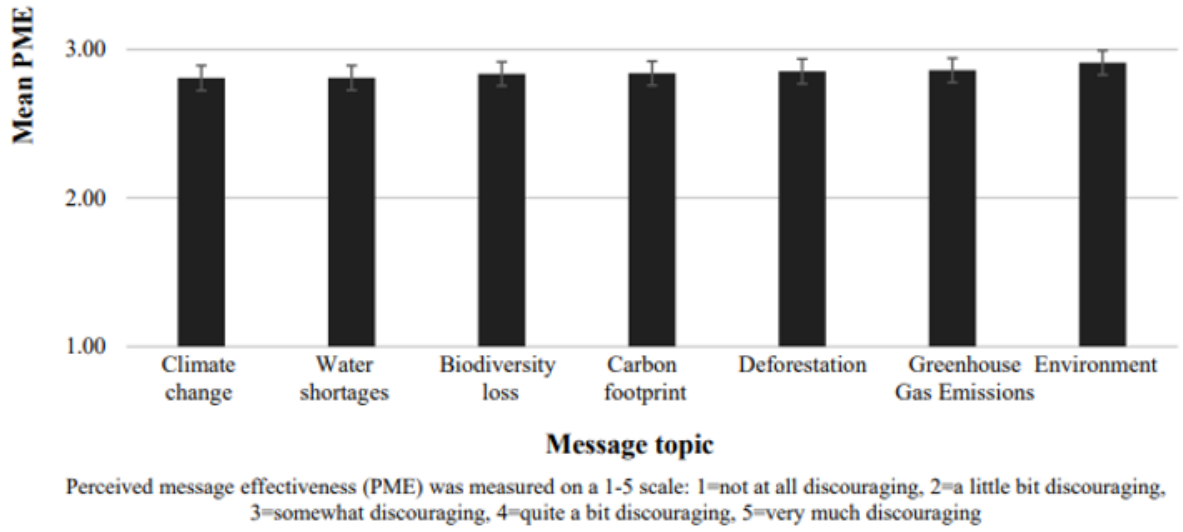


Figure 18: The efficacy of messages by impact topics sent to 1078 U.S adults (Wistar et al., 2022).

The ranking of the messages by topic effectiveness can be seen in Figure 18. On a scale of 1 to 5, the climate change topic impacted the audience by the lowest (2.81) and the overall environment topic effected at the highest (2.91). There has been a very slight difference observed across all 7 impact topics in relation to their discouraging effectiveness, all seven topics measured between: 'little bit discouraging' to 'somewhat discouraging' (Wistar et al., 2022).

The messages perceived by the participants, elicited lower effectiveness amongst people aged over 40 compared to the younger generation aged 18 – 29 (b = -0.10). The messages made also lesser impact amongst people who consumed beef more than once a week opposed to the ones whose intake was less than once a week (b = -0.10). The messages made bigger impact on partakers with higher degree than high school (b = 0.10) and for Latinos (b = 0.09) compared to lower education people and non – Latinos (Table 28) (Wistar et al., 2022).

Table 28: Regression of ordinary least squares result of the effectiveness of the messages (Wistar et al., 2022).

	Coefficient	*p* Value	95% CI	Standardized Coefficient
Aged over 39 (vs. between 18 and 29)	−0.28 *	0.013	−0.49, −0.06	−0.10
Aged between 30 and 39 (vs. between 18 and 29)	−0.06	0.507	−0.25, 0.12	−0.03
Eats beef more than once a week (vs. once a week or less)	−0.26 ***	0.001	−0.41, −0.11	−0.10
More than high school (vs. high school or less)	0.24 **	0.005	0.08, 0.41	0.10
Latino ethnicity (vs. non Latino ethnicity)	0.21 **	0.005	0.07, 0.36	0.09
Male (vs. female) †	0.06	0.455	−0.10, 0.21	0.02
Income between $35,000 and $74,999 (vs. less than $35,000)	−0.02	0.842	−0.20, 0.17	−0.01
Income of $75,000 or more (vs. less than $35,000)	0.19	0.068	−0.01, 0.40	0.07

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. † We do not report the coefficient for transgender (relative to female, reference gender category) due to small cell size ($n = 5$).

In conclusion, this experiment was conducted to encourage people to consume less beef meat due to its harmful impact on the environment. The partakers whose received messages about the harmful impacts received these messages framed in different ways. There has been no significant effectiveness difference addressed between the messages framed in worsening harms text and the reduction harms framed text, however the worsening ecological impact version tend to be stronger than the other version. All communication had a meaningful strong message, the topic 'environment' elicited the most powerful responses from the participants. It would require further research to understand the effectiveness of the word 'environment' in future messages or more specific terms would need to be used to make the encouragement more powerful. It is still controversy whether stressing the negative or positive impact outcomes

could make the bigger impact on people to encourage their red meat intake. Researches conducted in the future may make a bigger focus on the target population and their targeted messages, based on the differences observed amongst people with different education level, gender, ethnicity and age. Further assessment is recommended to plan the winning strategy to target the participants. (Wistar et al., 2022).

5.4.2 Mixing Meat with Plant - Based Alternatives

The attachment to meat is greatly observed in many countries based on researches and studies. This is mainly due that consumers can't really imagine having their meals without any meat involved as it's an important part of their diet. The option for skipping meat for certain period or even for a meal only is an unlikely happening option. For those people who wouldn't want to substitute their meat with vegetarian or vegan alternatives, meat blended with plant ingredients can offer a more sustainable possibility to reduce their meat intake. In this scenario, only a certain percentage of meat (approx.15% to 50%) would be substituted with plant – based ingredients, hence the meaty characteristic of the product would still remain as the original version. Due to the known environmental impacts, detrimental health effects, animal welfare issues, introducing new alternative proteins to the daily diet become significantly important. Plants offer a wide variety of substances which can replace meat up to a certain threshold. These plants can be mushroom, wheat, textured pea and soy protein, legumes such as chickpeas, beans, lentils, etc. These products offer a healthier and more sustainable product, although as these products are being somewhat novel, without a adequate information brought to the public highlighting its benefits, scepticism and reluctant behaviour may follow. Tailored information provided to the public can support the transition and offer clearly promoted alternative options for people (Profeta et al., 2021b).

An online experiment was conducted for determining consumer choices, their approach towards plant - based alternatives, i.e., mixing meat with plant ingredients. It is to be highlighted that when it comes to meat alternative products, consumers are looking to get a very similar experience, based on taste, texture, smell, appearance, nutrition, cost, etc. Most of the people particularly in the Urban West are not fully aware of the negative environmental impacts the meat industry is causing and prioritizing the sensory pleasure rather than the rising concerns. A study conducted among people with all dietary preferences showed that omnivores are the least concerned about animal welfare and vegans and vegetarians expressed their most concern about the ethical way of slaughtering animals. Meat products have been a main element

of our diet since centuries. This study revealed, that most of the people recognizes meat products as a healthy choice due to its nutritional value. The majority of people following an omnivorous diet, refuses to acknowledge the environmental impacts red meat is causing and associates red meat consumption as part of a healthy lifestyle. They perceive meat substitutes artificial and unhealthy. Clearly communicated promotion and description of meat alternatives are needed for the future. A topic of food neophobia (FNS) became a novel subject over the years as it affects the diet of many people. It's basically regarded to reluctance to try new food. Elderly people might tend to be more reluctant towards new types of food, particularly plant – based meat. They see meat in a traditional way, coming from animal farms not from processed plants (Profeta et al., 2021b).

The survey involved 501 strictly meat eater participants, hence vegans and vegetarians were not invited. Half of the partakers had to be the food shopper of the household. The gender ratio of the population of the study was almost half and half for male (245) and female (256). The most amount of people (100) in the age groups were aged between 35 – 44 years, followed by 99 people aged between 45 – 54, and the third largest age group (94) was between 25 – 34 years. 229 people had secondary school education, 122 people completed a bachelor or master degree, in the other hand, 22 people had no school education (Table 29) (Profeta et al., 2021b).

Table 29: socio-demographic breakdown of the study (n=501) (Profeta et al., 2021b).

Sociodemographics of the sample.

attribute	characteristics	n*	%
gender	Male	245	48.9
	Female	256	51.1
federal	Bruxelles	62	12.4
state	Brabant wallon	27	5.4
	Hainaut	68	13.6
	Liège	44	8.8
	Luxembourg	13	2.6
	Namur	27	5.4
	Antwerpen	88	17.6
	Provincie Limb.	20	4.0
	Oost-Vlaand.	58	11.6
	Vlaams-Brab.	60	11.9
	West-Vlaand.	34	6.8
age	< 25 years	59	11.8
	25-34 years	94	18.8
	35-44 years	100	20.0
	45-54 years	99	19.8
	55-64 years	71	14.2
	> 64 years	78	15.6
education	no school qualifications	22	4.4
	Still in school	18	3.6
	Junior High Diploma	20	4.0
	High school diploma	229	45.7
	University-entrance Diploma	78	15.6
	Bachelor or Master degree	122	24.4
	Other degree	12	2.4

* n = sample size

Figure 19 depicts the preferred locations of the participants sourcing their meat and meat products. The traditional retail shop was the most preferred (45.5%), followed by discount stores (23.6%) and traditional butchers (23.0%) as the top three favourites, the other options were minority (Profeta et al., 2021b).

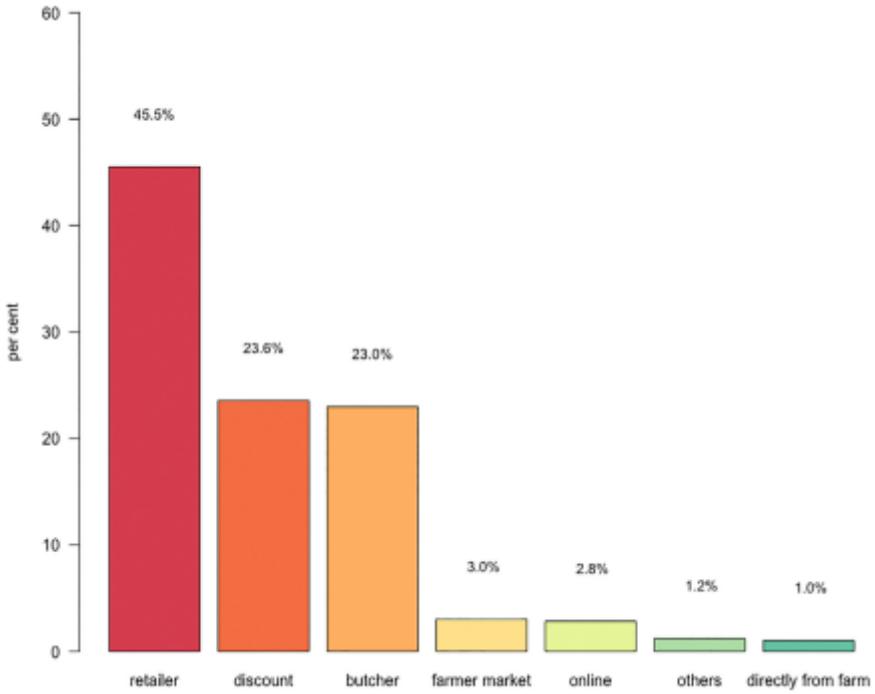


Figure 19: Chart of the preferred locations of meat purchase (Profeta et al., 2021b).

The survey questions were framed in two ways, in a reversed and in a non – reversed way. In a scale of 1 to 5, where 1 is strongly disagree and 5 is strongly agree, the highest valued statements were for ‘Meat reminds me of disease’ (3.70), and ‘I love meals with meat’ (3.69). Otherwise, all statements received a mean value between 3.07 and 3.70. The answers of the statements indicates that the participants deemed meat as an important part of their diet, rather than an unhealthy option (Table 30) (Profeta et al., 2021b).

Table 30: Scale of meat attachment questionnaire (MAQ) (Profeta et al., 2021b).

statement	std. α[1]	$\bar{x}$[2]	σ[3]
I love meals with meat.	0.84	3.69	1.03
To eat meat is one of the good pleasures in life.	0.84	3.36	1.10
I'm a big fan of meat.	0.84	3.58	1.07
A good steak is without comparison.	0.85	3.43	1.13
By eating meat I'm reminded of the death and suffering of animals.(r)	0.87	3.42	1.25
To eat meat is disrespectful towards life and the environment.(r)	0.87	3.23	1.12
Meat reminds me of diseases.(r)	0.87	3.70	1.15
To eat meat is an unquestionable right of every person.	0.86	3.60	1.05
According to our position in the food chain, we have the right to eat meat.	0.87	3.33	1.20
Eating meat is a natural and indisputable practice.	0.85	3.58	1.00
I don't picture myself without eating meat regularly.	0.85	3.44	1.10
If I couldn't eat meat, I would feel weak.	0.85	3.07	1.07
I would feel fine with a meatless diet.(r)	0.86	3.11	1.11
If I was forced to stop eating meat, I would feel sad.	0.85	3.35	1.14
Meat is irreplaceable in my diet.	0.85	3.29	1.02

Note: 5-point Likert scale: 1=strongly disagree, 2=disagree, 3=neither disagree nor agree, 4=agree, 5=strongly agree).

[1] std. α = standardized Cronbach's alpha.

[2] $\bar{x}$ = mean.

[3] σ = standard deviation.

The willingness towards meat substitutes was embedded in the questionnaire also (Figure 20). The respondents revealed that they intentionally replace meat with alternatives when they don't want to eat meat (yes: 58.7% and no: 41.3%). Concrete answers were required from the group to rank their preferred meat substitutes (Table 31). It can be seen that the first two favourites are also animal derived alternatives, fish (66.7%) and eggs (58.8%), followed by pasta (36.7%), another animal product cheese (29.6%) and salad (16.7%) as the fifth preferred option in the scale. Lentils, nuts and legumes were in mid – level (6.5% - 10.9%). The 100% plant based vegan alternatives received low preference like tofu (5.1%), tempeh (1.0%) and seitan (0.7%), which received the lowest liking (Profeta et al., 2021b).

Table 31: Ranking of meat alternatives (Profeta et al., 2021b).

Ranking list consumed meat alternatives.

rank	product	%
1	Fish	66.7
2	Egg(s)	58.8
3	Pasta	36.7
4	Cheese	29.6
5	Salad	16.7
6	Lentils	10.9
7	Nuts	6.5
8	Other legumes	5.4
9	Tofu	5.1
10	Other	2.3
11	Tempeh	1.0
12	Seitan	0.7

Figure 20: Deliberate meat substitution (Profeta et al., 2021b).

Direct questions about food neophobia were included in the online survey also (Table 32). The same 5 point like scale applied to the answers also where 1 is totally disagree and 5 is strongly agree. All of the statements received a mean value between 2.45 and 3.16. In relation to openness towards new types of food alternatives, some participants were constantly looking for new options (2.79) but on contrary, some did not trust any new food at all (2.81). The participants had to send their response about how often do they buy organic and / or free - range mat. 24.4% of them never, 57.7% of them sometimes, 15.2% of them often and 3.0% of them always purchase those meats (Profeta et al., 2021b).

Table 32: Scale of food neophobia (FNS) (Profeta et al., 2021b).

Statement	std. α^1	$\bar{x}^2$	σ^3
I am constantly sampling new and different food. (r)	0.74	2.79	1.14
I do not trust new (different or innovative) food.	0.75	2.81	1.05
If I don't know what a food is, I won't try it.	0.75	3.16	1.08
I prefer food from different cultures. (r)	0.75	2.92	1.03
I am reluctant to eat foreign food that I see for the first time.	0.72	2.86	1.17
If I go to a buffet, meetings or parties, I'll eat new food. (r)	0.73	2.45	0.99
I'm afraid to eat food that I did not eat before.	0.72	2.66	1.18
I am very particular about the food I eat.	0.74	3.00	1.26
I will eat almost anything. (r)	0.75	2.67	1.20
I like to try new ethnic restaurants. (r)	0.73	2.61	1.07

The survey was also looking for answers about how often did the participants purchase vegan, plant – based meat substitutes, such as mimicked burgers, sausages, vegetable burgers, etc (Table 33). Unexpectedly 41.3% of the group had never purchased any of those products. 14.6% tried some once, while 23.3% rarely, 16.6% sometimes and 4.4% frequently purchased those meat alternative products (Profeta et al., 2021b).

Table 33: Meat alternative intake frequency (i.e. mimicked burgers, sausages, vegetable burgers, etc.) (Profeta et al., 2021b).

	%
never	41.3
tried it once	14.6
rarely	23.2
sometimes	16.6
frequently	4.4

To get a better understanding of what plant ingredient blended into a meat product mean, the online survey included a task for the group of 501 people to compare a 100% meat product with a same type, but 40% plant protein mixed in, so the ratio of meat reduced to 60% (Table 34). The survey looked for an answer for which product they thought is healthier, tastier, more costly, better for the planet, better for the animals, the participants would pay a higher amount for and which one would they choose? In relation to animal welfare and ecological impacts, the hybrid option was perceived better (above 50%), also the hybrid version deemed to be more expensive (45.6%). Opposedly, in all other questions the meat product was perceived as a better option. The partekers found meat healthier (45.3%), tastier (62.7%) and they would spend more (37.1%) and choose a meat product (62.5%) than the mixed alternative (28.5%) (Profeta et al., 2021b).

Table 34: Perception comparison between a 100% meat product and a protein blended product (60% meat – 40% plant protein) (Profeta et al., 2021b).

	meat	neither/nor	hybrid
healthier	45.3%	14.4%	40.3%
tastier	62.7%	14.0%	23.4%
more expensive	36.5%	18.0%	45.6%
better for environment	22.6%	24.2%	53.3%
better for animal welfare	20.2%	28.9%	50.9%
I would pay more for ...	37.1%	42.3%	20.6%
I would choose ...	62.5%	9.0%	28.5%

As a result of this online survey involved a group of 501 meat eaters in Belgium, demonstrated that over 50% of them look for meat alternatives when it comes to food. It's been revealed that the main indication behind this was thoughtfulness for animal welfare and environmental impacts. In between the 1 to 1 comparison of a meat product versus a blended product, 28.5% of the interviewees opted for the plant enhanced product. Even though the plant version turned out to be more expensive than the meat version, these results show the open mindset and willingness towards a more sustainable idea. Further researches would need to be conducted to understand the expectations of the consumers about taste, look, smell. These factors are key for food manufacturers to develop and produce the right products in the future, which can offer a wider range of healthy and tasty blended alternatives for a more sustainable future (Profeta et al., 2021b).

Chapter 6 – Conclusion, Limitations and Future Research

6.1 Conclusion

This thesis reviews the background of the animal derived and a plant – based food consumption from health effects and environmental impact point of view. The assessment focuses on a comparison between a traditional animal food derived product, a beef burger and an equivalent plant – based alternative product, the Impossible Burger. The main goal of this study is to have a clearer view of the differences between an omnivorous and plant - based diet, from health effects, nutritional status, consumer motivations and environmental impacts.

The rise of the global temperature, natural disasters, wild fires are amongst the headlines which are making the news more and more frequently in the last few years. The covid 19 pandemic has shown the world, that how a leaked virus originated from an animal can literally terminate the whole planet and affect the health of the population. The avoidance of future outbreaks depends on how animal farming, slaughtering and trading are managed in the future as the animal industry holds a strong potential risk.

Due to the rapid growth of the world population (approx. 8 billion nowadays) which is expected to reach nearly 10 billion by 2050 rises a far – reaching question for the future: what will these people eat and how the food will be made to keep it sustainable for the planet. Animal derived food, meat has always been in high demand as it's been the main protein source. Multiple studies corroborated, that excessive animal origin food, particularly red meat consumption can lead to obesity and then to cardiovascular diseases. Type II diabetes, colorectal cancer, stroke have been linked with red meat consumption, which makes the future of food question even more challenging. The Eat Lancet commission has been established to tackle this question. Reports showed, that adherence to a vegan diet can significantly reduce the risk of cardiovascular diseases and other health issues.

Whether the omnivorous diet or the vegan diet, the main motivations of consuming either type of foods were mostly the liking factor and the perceived healthy status, based on surveys when people were directly asked why they eat what they eat. Animal welfare and environmental sustainability is mainly important for people who follow the plant – based diet.

Plant – based foods are earning more fame in the last decade. In some countries, the consumption of meat had decreased and the demand for alternative option has been

continuously rising. Due to animal welfare, environmental threats that the world is facing with and based on novel trends, food manufacturing companies started to offer meat substitutes, mimicked products made of plants, which try to deliver a similar satisfaction for consumers. Impossible Burger in the U.S, Strong Roots and Plant–It in Ireland became the flagship companies of offering meat alternatives for the consumers.

There have been multiple studies and reports made to address, that people whom are following a vegan diet are lacking of essential nutrients and minerals which are essential for the human being, therefore it may cause detrimental health effects. In these reports the concerns were about the essential amino acid intakes in vegan diet and a lack of vitamin consumption like B12, iodine, zinc and iron. These negative assumptions have been corroborated in many opposition studies, that a vegan diet can provide all essential nutrients with vitamin fortified foods and additional supplementation to maintain a healthy lifestyle.

The understanding and knowing of the nutritional value of any food started to interest the consumers more seriously. The nutritional comparison of a meat - based product and a plant – based product showed, that the outcome of the analysis has indicated that plant- based meat substitutes can offer a similar or even better nutrient profile, particularly in level of protein, fatty acids, fibre, minerals, to the homonymous version. As a result of the report, PB burger can offer an adequate alternative for the flexitarian individuals to achieve their goal to consume nutrient rich healthy food, while being more sustainable and less harmful for the animals.

The thesis is particularly focusing on the environmental impact differences between the consumption of a kilogram of a traditional beef burger and the Impossible Burger. The consumer who chooses the latter option, reducing the environmental impact by 87% to 96%. It results a 27.1kg of CO2 emission decrease, 87% of lesser clear water usage and land usage by 96%. Beef cattle to be fed to humans require a much greater resources than plant production. As an overall result reported by the survey conducted the comparison between the two products, alternating beef with Impossible Burger offers more sustainable ecological benefits.

Meat alternatives are widely available in food stores for the consumers, but the reasons why meat should be replaced at least time to time are not entirely known by the people. Environmental impact information messages were texted to partakers in a study to highlight the meat caused impacts on the planet to encourage people to reduce their meat intake for the sake of the future of the planet.

This study provides valuable information about the health effects and ecological impacts when choosing an omnivorous or plant – based diet. The new perspectives of vegan diet and plant – based food alternatives acquired through this study are essential for understanding, that there is a satisfying way for a more ethical and sustainable food culture, for more healthy people and mainly for a thriving planet.

6.2 Limitations

There are some notable limitations in this research. Due to time constraints, there was no survey conducted personally about what drives people when they choose their daily food and diets.

There was no data available online and offline from the chosen two leading Irish vegan food companies, the Strong Roots and Plant-It, to bring a more novel review about the Irish vegan food alternatives.

There was very limited data available for vegan alternative products for nutritional, health effects and environmental impacts comparison reason.

6.3 Future Research

Plant – based substitute products amongst the younger generation and mostly females was proven to be quite popular as an alternative to a meat product. Despite the popularity, the amount of new product launches aimed at the growing demand are limited at present. New product developments will be essential for the future to provide a wider selection of meat and dairy alternatives, particularly lesser processed versions to make them even more natural.

A more focused education about global warming would be needed also to ensure people are aware of the impacts and the direct connection between meat and dairy consumption and climate change. The threating climate situation calls for a larger cohort assessment study to analyse the direct linkages between food consumption and environmental sustainability and more importantly an information centre where all facts and solutions are easily available for

review. Surveys and information sharing supported by the relevant government authorities could effectively deliver the message to the population. Understanding of the different motivations, habits, why people eat what they eat and why people are reluctant to changes could make companies to manufacture more suitable products, it could make the relevant authorities to support and encourage the necessary changes.

Carbon taxes have been long introduced and recently increased in many countries including Ireland also. Future further increases might be necessary to pressurize companies to alter their businesses and opt for a more sustainable services and products.

The cost of the plant - based products have started at a very high price when the products were introduced in the past years, this is mainly due to the high price of novel technologies, and low demand in the past. This has been toned down in the recent years, so the price gap between a kg of beef product and a kg of a plant substitute is continuously shrinking, even in some countries had turned vice versa very recently. The price decrease of PB products is essential, parallel with a growing demand, it has a chance to create an affordable price - value parity.

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