FACULTY OF TECHNOLOGY

Carbon Footprint of Food Services at the University of Oulu

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ENVIRONMENTAL ENGINEERING
Master’s thesis
June 2023

ABSTRACT

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University of Oulu, Environmental Engineering

Master's thesis 2023, 105 pp. 1 appendix

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This thesis examines the impacts of food on biodiversity and quantifies the carbon footprint of food services at the University of Oulu. It aims to provide recommendations for reducing the carbon footprint of food services and minimizing the impacts on biodiversity. The motivation for the study is that reducing the carbon footprint and biodiversity impacts of food services are necessary to achieve carbon neutrality and sustainability goals.

The carbon footprint of food services at the University of Oulu was calculated as 770tCO_2eq for the year 2022. Food categories identified as top contributors to carbon footprint and biodiversity impacts are meat and dairy milk products; therefore, their consumption should be reduced.

To reduce carbon footprint, five scenarios were considered, each offering potential solutions. The most effective scenario involves substituting all meat and milk consumption with plant-based alternatives, resulting in a 50% reduction in the carbon footprint. Another scenario focuses on substituting 60% of meat consumption with low-carbon footprint fish, broiler, and plant-based products, leading to a 22% reduction in the carbon footprint. It is important to systematically address the substitution of high-carbon footprint food items with low-carbon footprint alternatives, in order to achieve carbon neutrality objectives.

To motivate sustainable and low-carbon footprint food choices, substituting plant-based alternatives and diversifying recipes while maintaining the sensory pleasure of meals is crucial. Offering a number of vegetarian or vegan meals, price rewards, and supporting environmentally conscious suppliers are effective strategies. Good communication with restaurant providers and customers is also essential, including sharing research findings, utilizing customer feedback, and implementing innovative recipes and meal plans. Balancing customer satisfaction with climate mitigation and sustainability goals is a top priority for restaurants.

Several limitations regarding the data uniformity and reliability have been identified in the study. Suggestions and recommendations were provided for successful future work and other related research studies.

Keywords: carbon footprint, food services, biodiversity impacts of food, climate mitigation

FOREWORD

This thesis was carried out as a project of the Carbon Footprint working group in the Water, Energy and Environmental Engineering Research Unit of the University of Oulu. The main goal is to contribute to reducing the carbon footprint of the University of Oulu and identify the biodiversity impacts related to food consumption at the university. The working period for the thesis was from February 2023 until June 2023. This thesis work was supervised by Prof. Eva Pongrácz and Julia Kiehle.

I would like to extend my gratitude to my supervisors Eva and Julia for their expertise, insightful feedback, and continuous encouragement which sharpened my research and refined the quality of this thesis.

My heartful appreciation goes to my beloved husband, for his unwavering support, patience, and belief in me have been a constant source of motivation. I am also grateful to my parents, sister, and friends for their encouragement, and love throughout this journey.

Oulu, 07.06.2023

Dilshika Heenatigala Kankanamge

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LIST OF ABBREVIATIONS

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CO2	Carbon Dioxide
CO2eq	Carbon Dioxide Equivalent
CF	Carbon Footprint
GHG	Green House Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standardization Organization
LCA	Life Cycle Assessment
Luke	Natural Resource Institute Finland (Luonnonvarakeskus)
CH4	Methane
N2O	Nitrous Oxide
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

1 INTRODUCTION

Climate change is one of the controversial global issues where solutions are provided and practiced worldwide. (IPCC 2014) Climate impact is linked with biodiversity loss, overconsumption, unhealthy dietary patterns, and unsustainable lifestyle (Vermeulen et al. 2012). Therefore, the actions taken toward climate mitigation play a vital role in these sectors. Carbon footprint (CF) is an effective tool to measure the carbon dioxide (CO2) emissions of a company or institute (Poore and Nemecek 2018). To achieve the carbon neutrality goals, measuring CF and reducing it sectoral wise is important.

The Finnish government's climate policy to be carbon-neutral by 2035 encourages all companies and institutes to develop carbon-neutral pathways individually. Finnish Universities are planning to achieve carbon neutrality by 2030 (UNIFI 2021). The University of Oulu had calculated its carbon footprint for the past four years (2018 – 2021). In line with its commitment to environmental sustainability, the university has set a goal to reduce its CF by 50% from the levels observed in 2019 by the year 2025 (University of Oulu 2021).

Sectoral involvement in a CF is required to be considered individually and make decisions. Restaurant services/food services including catering services which contribute 6% of the total CF in 2021 are identified as a sector that requires special attention and expects to address with necessary methods of carbon compensation.

Food is an essential basic necessity for human survival and well-being. However, every stage of the food chain, starting from production to consumption and disposal, has a profound impact on biodiversity and contributes significantly to emissions (Vermeulen et al. 2012). The overall emissions and biodiversity impacts of a particular food variety depend on its lifecycle, encompassing processes such as agricultural practices, storage, transportation, processing, packaging, and waste management (Garnett et al. 2015).

Restaurants or cafeterias at educational institutes and workplaces play a vital in Finland's dietary habits (Raulio et al. 2010). With a significant portion of the population relying on these food services for their meals, the choices and practices implemented within these establishments have a considerable impact on the overall dietary patterns and nutrition of Finns. Therefore, it becomes crucial to address and mitigate the climate impacts and biodiversity threats associated with these food services to promote sustainable and environmentally friendly dietary habits among the population.

The objectives of this thesis are to:

1. Assess the biodiversity impact of food consumed in university restaurants.
2. Calculate the carbon footprint of food services at the University of Oulu.
3. Provide suggestions on how to reduce the carbon footprint of food services.

The thesis will examine the relationship between food and biodiversity, encompassing the entire food cycle from cultivation to waste disposal. Moreover, the cross-border impact of food utilization between countries will also be discussed. To calculate the carbon footprint of food services, data was obtained from two major restaurant service providers at the university, Juvenes, and Uniresta.

The subsequent chapters of this thesis are structured as follows: Chapter 3 focuses on carbon footprint calculation and emissions associated with the food system, while Chapter 4 provides insights into the Finnish food system, including patterns of consumption, production, import statistics, and the biodiversity impact of the Finnish food system. Chapter 5 presents the background of the university's food services, leading into Chapter 6, which highlights the calculation results and their assessment. Chapter 7 encompasses the identification of emission and biodiversity hotspots within the restaurant services at the university. It further explores scenarios for reducing the carbon footprint, practical measures to be implemented, and the limitations inherent in the calculations. Finally, Chapter 8 concludes the research and provides suggestions for mitigating the CF based on the obtained results.

2 FOOD AND BIODIVERSITY

2.1 Biodiversity

Biodiversity refers to the variety of life forms found on Earth including plants, animals, and micro-organisms. The variety specifies the genetic, species, and eco system diversity in life. (Secretariat of the Convention on Biological Diversity 2020). It is an essential component of the functioning of ecosystems and the provision of eco system services. Eco system services are divided into four categories: - Provisioning services including food water and air, regulating services including climate regulation and water purification, cultural services including recreational, and spiritual values, and supporting services including nutrient cycling, and pollination. (Millennium Ecosystem Assessment 2005). Thus, maintaining the ecological balance and ecological functioning is beneficial to human societies. (IPBES 2019)

2.1.1. Genetic diversity

Genetic diversity is the variety of genes within a species or population including differences in genetic traits and characteristics (Secretariat of the Convention on Biological Diversity 2010). It is essential for the survival and evolution of species, as it provides the genetic variation needed for populations to adapt to changing environments, resist diseases, and maintain reproductivity (Hoban et al. 2020). Several factors including genetic mutations, recombination, gene flow, and genetic drift influence these processes (Laikre et al. 2010).

2.1.2 Species diversity

Species diversity is the variety of different species present in a given ecosystem, including the number of species, their relative abundance, and their distribution (Secretariat of the Convention on Biological Diversity 2014). It can be known as a key indicator of ecosystem health and resilience since it affects ecosystem stability, productivity, and functioning (Secretariat of the Convention on Biological Diversity 2010). High species diversity within an ecosystem provides resistance to invasive species and diseases (Tilman et al. 2014). Lack of genetic diversity leads to disease outbreaks, pests, and other environment-related stresses.(FAO 2010) Furthermore, the diversity of species has social and cultural significance, providing aesthetic, recreational, educational, and spiritual values to human societies (Secretariat of the Convention on Biological Diversity 2010)

2.1.3 Ecosystem diversity

Ecosystem diversity refers to the variety of ecosystems, such as forests, wetlands, grasslands, and marine environments, and the interactions between different ecosystems in a given area. Climate, geology, and geography play a critical role in maintaining the stability and resilience of the planet's ecosystems (Secretariat of the Convention on Biological Diversity 2010). Balancing and functioning of nature are maintained by ecosystem diversity, through its unique services provided, such as nutrient cycling, pollination, water purification, and climate regulation. (Millennium Ecosystem Assessment 2005). Water quality is maintained by wetlands and forests which remove sediments, nutrients, and contaminants from water, and make sure it is of suitable quality (Millennium Ecosystem Assessment 2005). Microorganisms in the soil such as bacteria and fungi break down organic matter and release nutrients that are required for plant growth (FAO and ITPS 2015). Pollinators are important for the production of different crops including agricultural crops (IPBES 2016).

2.2 Relation of the food system to biodiversity

The food system is one of the most significant relationships between biodiversity and life. Food is a fundamental human need that provides the necessary nutrients for growth, maintenance, and other body processes. Biodiversity is a crucial factor for the food system due to the numerous essential ecosystem services provided. The journey of food from farm to fork involves various stages including food producing, processing, distributing, and consuming. These stages encompass agricultural production and livestock farming to food processing, packaging, storage, transportation, retailing, consumption, and disposal of waste. The overall food system has both positive and negative impacts on biodiversity. Agriculture which includes both crop cultivation and livestock is a major contributor to biodiversity loss, accounting for 40% of global loss (Wilting et al. 2017).

2.2.1 Land use change

Land use change, including deforestation and conversion of natural ecosystems to agricultural land, is one of the crucial biodiversity losses (Newbold et al. 2015). Land types mostly impacted by land use change due to food systems are forests, grasslands, wetlands, and coastal areas. Deforestation, which involves the clearing of forests, agriculture, or related infrastructure development, is a major type of land use change that impacts forests. Deforestation can result in the loss of important habitats for many species, including endangered and endemic ones, and can lead to changes in species composition, fragmentation of landscapes, and loss of biodiversity. (Foley et al. 2005)

Conversion of natural grasslands to croplands or pasture involves the transformation of native grasslands into agricultural lands for cultivation or grazing of livestock (Foley et al. 2005). Overgrazing of livestock leads to the degradation of natural habitats, particularly in arid and semi-arid regions. Altering soil structure due to overgrazing impacts soil organisms and thereby nutrient depletion. Soil erosion and loss of vegetation cover cause threats to biodiversity and ecosystem services. (Eldridge et al. 2010) The limit of grazing depends on various factors such as plant growth rates, species composition, and environmental conditions, and is typically determined based on the carrying capacity of the land, which is the maximum number of animals that can be sustained without causing degradation. (Derner et al. (2009)).

Wetlands, such as marshes, swamps, and bogs, are often drained or converted to agriculture or urban development, resulting in land use change that can have detrimental impacts on wetland ecosystems. Wetlands are crucial habitats for numerous species, including waterfowl, amphibians, and aquatic plants. Their loss can lead to declines in biodiversity and ecosystem services, such as water purification and flood regulation. (Mitsch et al. 2013) Coastal areas, including mangroves, salt marshes, and coral reefs, are also impacted by land use change. Coastal areas are often converted for aquaculture or crop cultivation resulting in the loss of important habitats for marine species and disrupting coastal ecosystem functions. (Alongi 2015)

Land use change leads to habitat fragmentation which ultimately becomes a driver of the loss of biodiversity and degradation of ecosystem services. Due to the loss of habitats, the fragmented remaining habitats are not sufficient to support viable populations (Haddad et al. (2015)). The decline in resource availability increases the vulnerability of species to predation are other threats posed (Tscharntke et al. 2012). Therefore, habitat loss directly leads to a decrease in the species compositions within the ecosystem.

Land use change is significantly associated with meat, milk products, and egg. Feed cultivation plays a vital role in this regard. The grain type required for feed production is different from the grain for food. The land area required for feed grain production is greater than the one for food grain. (Kortesoja et al. 2022) Soybeans, bananas, wheat, coffee, palm oil, and rice are some other highly consumed food varieties contributing to land use change and thereby habitat destruction. (Kortesoja et al. 2022))

Habitat destruction leads to species extinction. Global extinction footprint is a significant measurement tool for assessing the impact on biodiversity. It refers to the impact of human activities on worldwide species extinction risk (Ceballos et al. (2015)). This concept is used in conservation biology to measure the magnitude of human impacts on biodiversity loss using indicators such as species decline rates and the proportion of threatened species (IPBES 2019). The highest contributors to the global extinction footprint are food and agriculture, with respective contributions of 20% and 19% (Irwin et al. 2022).

Moreover, in terms of habitat destruction, several unsustainable fishing practices play a vital role. For instance, one of the most common methods of fishing is, bottom trawling which involves dragging a large net along the seafloor for fishing. This practice significantly destroys habitats including coral reefs, seagrass beds, and rocky outcrops. (Hiddink et al. 2017) Furthermore, overfishing and the use of destructive fishing methods have detrimental effects on non-target species and ecosystems (Jennings et al. 2016).

2.2.2 Soil Erosion

Soil erosion is another detrimental threat to biodiversity, which lead to the loss of topsoil, the most fertile layer of soil supporting plant growth. This loss of topsoil can result in the destruction of habitat for various plant species, including crops. (Montgomery and Matson 2007) Further, many microorganisms that play a crucial role in soil health and biodiversity are threatened by soil erosion (Six et al. 2004).

Soil erosion can also contribute to water pollution, as eroded soil particles can carry excess fertilizers, pesticides, and other agrochemicals into rivers and streams, negatively impacting aquatic biodiversity (Sharpley et al. 2013). Due to the fact that soil acts as a crucial carbon sink, storing large amounts of carbon in organic matter, (Lal 2004) soil erosion accelerates the loss of soil organic carbon, contributing to diminishing soil carbon storage (Stockmann et al. 2013).

Land use change, overgrazing, and unsustainable agricultural practices are major contributors to soil erosion. Intensive farming practices such as tillage, monoculture, and overgrazing can disturb the soil structure, remove the vegetative cover, and expose bare soil, increasing the vulnerability of soil to erosion (Montgomery and Matson 2007).

Monoculture farming refers to the cultivation of single-crop species on a large-scale farm over multiple growing seasons. This is used as an economically efficient and convenient farming practice. (Tilman et al. 2002) Coffee, bananas, soybeans, wheat, and palm oil are examples of crops that are following monoculture farming and have significant biodiversity threats.

2.2.3 Introduction of non-native species

Several agricultural mechanisms can facilitate the introduction of non-native species into the ecosystem which intentionally or unintentionally threatens biodiversity (Pyšek and Richardson 2010). Non-native species outcompete natives for resources which ultimately leads to the extinction of native species from a particular ecosystem (Mack et al. 2000). Further, this deviates the ecosystem balance and resilience. In terms of the productivity of crops, non-native species can cause significant economic losses by damaging crops and reducing the productivity of agricultural systems (Pimentel et al. 2005). As an example, the introduction of the citrus psyllid to California has led to significant losses in citrus production due to the spread of citrus greening disease (Grafton-Cardwell et al. 2013).

One common way of unintentionally introducing non-native species is seeds which are dispersed into nearby ecosystems through wind, animal, or water. Importing agricultural crops is another significant way of spreading non-natives over borders. (Seebens et al. 2018) The use of non-native livestock breeds or new crops can carry new varieties of pests and diseases which impact negatively native species. Further, in aquaculture, escapes of non-native farmed fish can lead to genetic mixing with wild populations, and non-natives can reduce genetic diversity and impact the ability of wild populations to adapt to changing environmental conditions (FAO 2020a).

2.2.4 Use of fertilizer, agrochemicals, and pesticides

Agrochemicals, including herbicides, insecticides, and fungicides, are widely used to control weeds, insects, and diseases, respectively. However, the use of these chemicals can also have negative impacts on biodiversity.

Although the chemicals are designed for an intended function, unintended consequences can impact non-targeted species. Many pesticides including insecticides and herbicides target harmful insects or weeds. However, other beneficial insects including pollinators and soil-dwelling organisms responsible for nutrient cycles can be impacted (Geiger et al. 2010). As an example, neonicotinoid pesticides have been linked to declines in bee populations (Woodcock et al. 2017). Further, other insects, mammals, and birds in contact with the targeted ones can also be harmed (Power 2010). The loss of insect populations negatively impacts the bird populations (Kortesoja et al. 2022). Additionally, herbicides can reduce plant diversity and habitat quality for wildlife. (Power 2010)

Widespread use of these chemicals leads to soil degradation, water pollution, and destruction of habitats which impacts biodiversity and ecosystem balance greatly. For instance, fertilizers can contribute to the eutrophication of water bodies (Paerl et al. 2018). Additionally, soil compaction is an indirect impact of pesticides due to the heavy equipment used for spreading pesticides in crop fields (Kortesoja et al. 2022).

2.2.5 Eutrophication

The eutrophication process occurs due to the excessive nutrient supply, primarily nitrogen and phosphorous, to a waterbody, leading to an inclination in plant growth for instance algal blooms (Paerl et al. 2016). This encompasses subsequent changes to the ecosystem and its functioning (Schindler 2012). Destroying fish populations and creating anoxic conditions in the water which are negatively impacting aquatic ecosystems are the main consequences caused (Carpenter and Bennett 2011). The food system is one of the major contributors to eutrophication which includes agriculture, aquaculture, food processing industries, and food waste (Galloway et al. 2013).

The use of nitrogen and phosphorous-based fertilizer in crop cultivation accumulates nutrients in soil and water which lead to eutrophication (Galloway et al. 2013). Moreover, when animal manure is mixed with soil and water due to poor manure management, has the potential to mix into waterbodies as a nutrient source (Withers and Haygarth 2007). Further, when manure is used as a fertilizer in crop fields, the potential risk of getting mixed with water is high. Aquaculture is another significant contributor to eutrophication. Fish feed contains high levels of nitrogen and phosphorus. The uneaten feed can accumulate on the bottom of waterbodies, which provide excess nutrients leading to eutrophication. (Troell et al. 2014)

Food processing industries release large amounts of organic matter and nutrients which are rich in nitrogen and phosphorous into wastewater (FAO 2013). For example, the dairy industry produces a large amount of wastewater with high levels of organic matter and nutrients due to the processing of milk and cheese. If the wastewater is not properly treated and mixed with natural water bodies, it can lead to eutrophication (FAO 2013).

Overall, meat and milk are the main food types that contribute to the eutrophication of water bodies. Feed cultivation again plays a vital role. Soybeans, which are widely used for feed, are an example of contributing to eutrophication. Crops for instance wheat, banana, and rice influence eutrophication with excess fertilizer usage.

2.2.6 Water Scarcity

Water scarcity refers to the situation where the demand for freshwater exceeds the available supply, posing significant challenges to human societies and ecosystems (Falkenmark and Rockström 2006). Agriculture is the largest consumer of freshwater globally, accounting for approximately 70% of total freshwater withdrawals (FAO 2020b).

A third of the total water footprint of agriculture in the world is due to animal products. (Mekonnen and Hoekstra 2012). The water footprint is an indicator used to measure the water levels consumed by a product or process. This can be categorized into three types: - which are blue green and grey. The blue water footprint refers to the loss of water consumption of groundwater and surface water for a product. The green water footprint refers to the loss of the remaining water absorbed in soil from the rain while the grey water footprint means the volume of freshwater that is required to assimilate a load of pollutants based on natural background concentrations and existing ambient water quality standards. (Hoekstra et al. 2011).

Animal products, cereals, nuts, and pulses have the highest water footprints globally. animal products including meat, milk, and egg contribute to excess usage of fresh water, due to the major fraction coming from feed cultivation. Beef production encompasses a third of the total water footprint of animal products. (Mekonnen and Hoekstra 2012).

2.3Food waste and food losses

Food waste and food losses are two distinct and interconnected issues in the food system. Food losses occur directly or indirectly at food production, processing, storing, packaging, and transportation while food waste is generated at the retail and consumer level. Food losses and food waste significantly impact biodiversity (FAO 2019). When food is wasted or lost, the resources used to produce it are also wasted, including water, land, and energy. This can lead to the degradation of ecosystems and the loss of biodiversity. (IPBES 2019)

At the production level waste occurs in different ways including pre-harvest and slaughter, during harvest and slaughter, and post-harvest and slaughter operations. (FAO 2019)

During the production phase of the food supply chain, waste can occur indirectly due to factors such as food left in the field due to quality standards or price drops in the market (Lipinski et al. 2013). This can happen when the product does not meet strict quality standards or when market prices do not justify the cost of harvesting, resulting in food being left behind in the fields. Additionally, direct losses can occur due to damages caused by machinery or labour during the harvesting process, poor harvest scheduling, and suboptimal agronomic practices and choices (Lipinski et al. 2013).

Similarly, during transportation, food can be lost indirectly due to improper transport facilities, such as inadequate temperature control or improper handling, which can lead to spoilage or damage. Prolonged storage due to lack of transportation or logistical mismanagement can also result in direct food losses during transportation. (Lipinski et al. 2013)

In terms of storage, poor management of refrigeration conditions is a major contributor to food losses. Suboptimal temperature and humidity control in storage facilities can accelerate spoilage and deterioration of food items, leading to significant losses. Food processing also indirectly contributes to food losses. Inadequate processing capacity for seasonal products can result in surplus produce that goes to waste due to a lack of processing facilities or insufficient demand. Moreover, technical malfunctions, such as damaged packaging or incorrect sizing, as well as management issues and excessive trimming required to obtain specific shapes or textures of food, can result in direct food losses during the processing and packaging stages. (Lipinski et al. 2013)

Food waste occurs directly through inappropriate product displaying and packaging, and indirectly at the retail stage by the variability in perishable food demand, removal of imperfect-looking food from stores, and overstocking. Food is wasted directly at the consumption stage by the consumers' confusion between expiration and preferred consumption dates, poor storage and stock, and oversized portions during a meal. Further, indirectly wasted due to the multitude of date labels, which means the food is wasted due to the consumer's confusion about printed labels on the food products. (Lipinski et al. 2013)

Food waste is disposed of in different ways in different countries. Landfills, incineration, anaerobic digestion and composting are common methods (FAO 2011). Anaerobic digestion and composting are known to be the methods with the least biodiversity and global warming impacts.

Composting is a biological process that involves the decomposition of organic materials, such as food scraps, yard waste, and other biodegradable materials, into a nutrient-rich amendment called compost. Improper use of composted material in agriculture leads to soil acidification which as a result will harm animals, soil dwellers and plant life (Hargreaves et al. 2008). Anaerobic digestion is a commonly used treatment method for food waste, which involves the breakdown of organic matter to produce biogas. The residual product of this process, known as digestate, is often utilized as fertilizer due to its nutrient-rich content (Slorach et al. 2019). However, it is important to note that the application of digestate as fertilizer can potentially contribute to soil acidification and eutrophication, depending on various factors such as food waste composition, soil type, application method, and weather conditions. (Slorach et al. 2019)

2.4 Transnational nature food system impacts

The transnational nature of the food system implies that the impacts on biodiversity can extend beyond the geographical area where food is produced and be felt in other regions where it is consumed. (Poore and Nemecek 2018) This involves multiple complex networks of actors, processes and flows that operate across national borders. Since the food is imported and exported across borders, the impacts of food are dispersed to the biodiversity of multiple countries.

Several species are threatened and added to nature red lists in developing countries due to food exports. According to a study by Irwin et al., (2022) North America, Europe, and East Asia are introduced as importers of extinction risk footprint since their consumption drives the extinction footprints and biodiversity threats in developing countries. For instance, Madagascar, Tanzania, Sri Lanka, Papua New Guinea, and Costa Rica are at the top of the list of impacted countries. Amphibian extinction footprint is the highest due to exports in Madagascar, Tanzania, Sri Lanka, and Costa Rica while in Papua New Guinea, the mammal extinction footprint is the highest. The export extinction footprint contributes to the total extinction footprint more than domestic consumption in these countries. (Irwin et al. 2022) Moreover, 187 exporting countries including the aforementioned, revealed that coffee, tea, cocoa, vanilla, cloves, processed food, and banana are the food items that have the highest impact on biodiversity (Lenzen et al. 2012).

Further, soybean cultivation in Brazil has been linked to deforestation in the Amazon rainforest. Deforestation for soybean production can lead to the displacement and extinction of wildlife species, such as the endangered Brazilian Amazon pink river dolphin and the vulnerable jaguar. (Nepstad et al. 2014) Additionally, palm oil, rice, coffee and banana are example food types that have high biodiversity impacts on their country of production due to exports. Unsustainable farming practices including, tillage methods, use of inorganic fertilizers, monoculture farming, and compaction of soil structure are some reasons contributing to biodiversity threats. (Kortesoja et al. 2022)

3 THE CARBON FOOTPRINT OF FOOD

3.1 Carbon footprint calculation

The CF is one of the essential and evolving tools used on the pathway to carbon neutrality. It is used to calculate greenhouse gas emissions in relation to products, processes, organizations cities, countries, etc. (Pandey et al. 2011) Gao et al. (2014) introduce it as a tool used to compensate for unavoidable Green House Gas (GHG) emissions. The system boundary is defined in order to identify the scope of the emissions considered for the study (Wiedmann and Minx 2007). CF is reported in mass units (Pandey et al. 2011).

Emissions are categorized into three different scopes by the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD). Figure 1 describes the three scopes. Scope 1 includes the direct emissions from the relevant activity while scopes two and three include indirect emissions from consumed energy, business travels, or commuting and waste disposals, respectively. (WRI and WBCSD 2004).

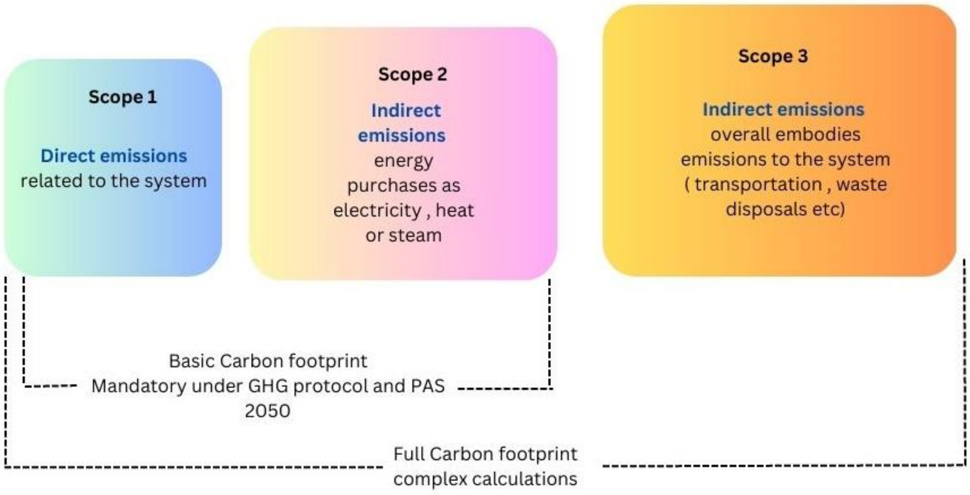

Figure 1. Scope and boundaries of CF calculation (retell from (Pandey et al. 2011).

A number of standards are available for following in order to calculate the CF. Some standards available are, the GHG protocol of WRI/ WBSCD, International Standard

Organization (ISO) 14064, Publicly Available Specification 2050(PAS 2050) of British Standard Institute (BIS), 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines for national Green House Gas inventories, ISO 1425 and ISO 14067.

Two methods are used for CF calculations, which are Life cycle assessment (LCA) and Input-Output Analysis (Pandey et al. 2011). The Life cycle assessment method is a cradle-to-grave approach (Pandey et al. 2011) for product-related CF calculations. It follows ISO standards ISO 14040 and ISO 14044 (Klöpffer and Grahl 2014). The whole lifetime of the product is considered from raw material acquisition to disposal after use (ISO 2006). Input-output Analysis is a top-down analysis used commonly in economic flow assessment on a large scale (Wiedmann and Minx 2007). It analyses the economic flows within an organization by considering the inputs and outputs (Ran Finnveden et al. 2009)

The CF calculation of a product or related economic process is shown in Figure 2. LCA analysis is conducted along the life cycle of the product according to ISO 14040 and ISO 14044 (Pandey et al. 2011). The first step is defining the goal and scope. The product life cycle is analyzed by identifying raw materials, manufacturing, distribution processes, consumer use disposal, or recycling methods. Each of these is considered in accordance with the functional unit. Then the system boundaries are determined for the CF calculation. The second step is the LCA study. The accuracy of CF depends on the emission data within the system boundaries of the whole life cycle. Crucial factors of accuracy are utilized in material amounts, activities, and emission factors through each stage of the product life cycle. Finally, results can be reported. (Gao et al. 2014).

When determining the CF of a category containing multiple sub-product categories, the emission factor is multiplied by the corresponding activity data. Emission factors are typically derived from LCA studies conducted for each specific product. For instance, when calculating the CF of food services within an organization, the quantities of food consumed are considered activity data, while the emission factors are determined based on LCA studies conducted for each food type utilized. Consequently, the total CF of food services is obtained by multiplying each food amount by the corresponding emission factors. (WRI and WBCSD 2004)

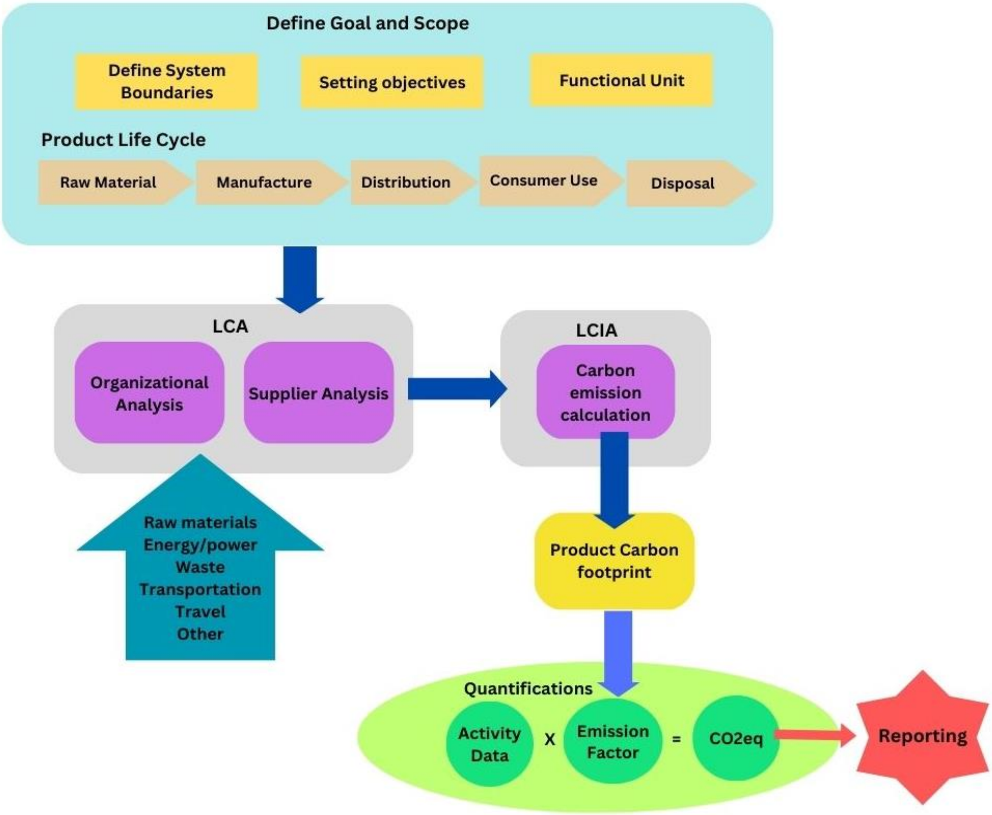

Figure 2. Carbon footprint calculation methodology (retell from Gao et al. (2014)).

3.1Emissions related to food

In 2021, GHG in the world are around 53 billion Carbon dioxide equivalent (CO_2eq) per year (Friedlingstein et al. 2022). The food system accounts for 21% - 37% of anthropogenic emissions which is around 18 billion CO_2eq, a third of global emissions. The highest contribution is CO_2 which is 52%, followed by methane (CH_4) at 35%, nitrous oxide (N_2O) at 11%, and 2% of fluorinated gases. (IPCC (2019)) CH_4 is a potent greenhouse gas with a global warming potential (GWP) 28 times greater than CO_2 over a 100-year time frame, while N_2O has a GWP around 265 times greater than CO_2 over the same time frame (IPCC 2013).

GHG emissions are generated at each stage throughout the food system, from food production, processing, packaging, retail, and consumption. The waste generated from all these stages is also responsible for a significant amount of GHG emissions. Emissions related to the food system can be divided into four categories, Land-based, energy, industry, and waste. Land-based encompasses emissions that occurred due to land use and land use change for food production including livestock and crop cultivation-related activities. These emissions can come from deforestation and other land management practices. The energy sector includes emissions related to the energy required for producing, processing packaging, transporting, retailing, and consuming food. This can include emissions from the use of fossil fuels in farming equipment, refrigeration systems, and vehicles. Waste includes the end-of-life of food and other waste generated at processing while industrial emissions account for emissions related to packaging material production and food production-related chemicals, including fertilizer and pesticide production and retail sector refrigeration. The waste category includes emissions related to the end of life of food and other waste generated at processing. This can include emissions from the decomposition of organic waste in landfills, as well as from the incineration of waste. (Crippa et al. 2021, 2022)

Food production is the largest emissions contributor to the entire food system which includes crop cultivation, livestock, fishing, and aquaculture. This accounts for 72% of the emissions related to the global food system (Crippa et al. 2021, 2022). Land use and land use change related to agriculture such as deforestation and conversion of grasslands and vegetation to croplands release significant amounts of CO_2 into the atmosphere. According to a study conducted by Havlík et al., (2014), by 2030, a more efficient agricultural system would be able to decrease 736 million metric tons of CO_2eq per year primarily by avoiding land conversions for agriculture. In addition, land use changes affect the balance of other GHGs which are emitted from soils, livestock, and other sources. Furthermore, an enormous amount of CO_2 is emitted by the fuel combustion or electricity utilized for equipment and machinery used in food production including crop cultivation, livestock, fishing, and aquaculture. This depends on the fuel or source of electricity used. (Crippa et al. 2021, 2022)

Crop cultivation, including both food and feed for livestock and aquaculture cultivation, is responsible for N_2O emissions (IPCC 2019). Due to the massive usage of nitrogen fertilizers for enhancing the harvest (IPCC 2018). Nitrogen fertilizer contains N in the form of ammonium or urea which are not readily available to roots to be absorbed. Therefore, it must first be converted to nitrate (NO_3^-) by nitrifying bacteria in the soil resulting in producing nitrate. It is later absorbed by plants and releases N_2O. (Hirsch et al. 2010)

Livestock is responsible for major CH_4 and N_2O emissions. CH_4 is produced by enteric fermentation in the stomachs of ruminant animals (such as cows and sheep) and pigs (IPCC 2018). Enteric fermentation is a process of digesting where microorganisms in the digestive tract break down fibrous feed materials, producing gases such as CH_4, CO_2, and hydrogen (H_2) (IPCC 2019). Moreover, inadequate manure management produces both CH_4 and N_2O by anaerobic digestion. This occurred when the manure is stored or treated in anaerobic conditions (i.e. non-oxygen environment). Methane is produced as a by-product of this process. (FAO 2006) Further, if the manure is applied to soil as a fertilizer, N_2O releasing potential is high when the soil bacteria convert nitrogen (N_2) in manure into nitrous gas including N_2O. (Chantigny et al. 2010)

The number of emissions generated from food processing accounts for 4% of global GHG emissions of the food system (Crippa et al. 2021, 2022). These emissions depend on the specific processes involved in the processing. Meanwhile, the packaging stage also contributes to CO2 emissions depending on the energy source used. 5% of GHG emissions from the food system come from packaging (Crippa et al. 2021, 2022). For instance, plastic packaging commonly utilized for food and beverage products contributes to emissions due to the extraction and processing of fossil fuels required for its production.

Transport alone accounts for 5% of total GHG emissions related to the global food system (Crippa et al. 2021, 2022). Transportation is involved in each stage of the food system. This includes emissions from the transportation of raw materials, processed foods, and finished products from farms and processing plants to retail locations and consumers. The emissions from transportation depend on various factors, for instance, the traveled distance, the mode of transportation, and the fuel source used. Transportation by truck and airplane tends to emit more CO_2 when compared the transportation by train or ship, Transportation powered by fossil fuels results in higher emissions compared to renewable energy sources. (Sims. R et al. 2014)

The retail sector contributes 4% of the global food system’s GHG emissions, mainly through energy consumption in stores and refrigeration systems (Crippa et al. 2021, 2022). Therefore, the emissions depend on the energy source used for electric heating and refrigeration. Food consumption accounts for 3% of total GHG emissions from the food system (Crippa et al. 2021, 2022). These emissions vary depending on several factors such as the types of food consumed, the amount of food wasted, the cooking methods used, and the source of energy used for cooking.

Refrigeration which involves each stage of food production has the potential of emitting primarily hydrofluorocarbons (HFCs) in addition to the emissions related to the energy used for refrigeration The HFCs are commonly used as refrigerants in commercial and domestic refrigeration, air conditioning, and heat pump systems which has a high global warming potential. (Global Food Cold Chain Council 2015) The leakage of HFCs during installation, operation, and maintenance of refrigeration systems is the main source of emissions from refrigeration. HFCs can also be emitted during the end-of-life disposal of refrigeration systems.

Various food waste disposal methods contribute to GHG emissions depending on the method and type of waste. Anaerobic digestion and composting which are two widely used food waste treatment methods in Finland, contribute to comparatively fewer emissions than incineration and landfills (Lipinski et al. 2013). The level of emissions depends on the composition of the waste and the waste management procedure (Dorward 2012).

Figure 3 illustrates the emissions related to each stage of the food system. Figure 4 represents the respective GHG emission contribution percentage of each stage of the food system.

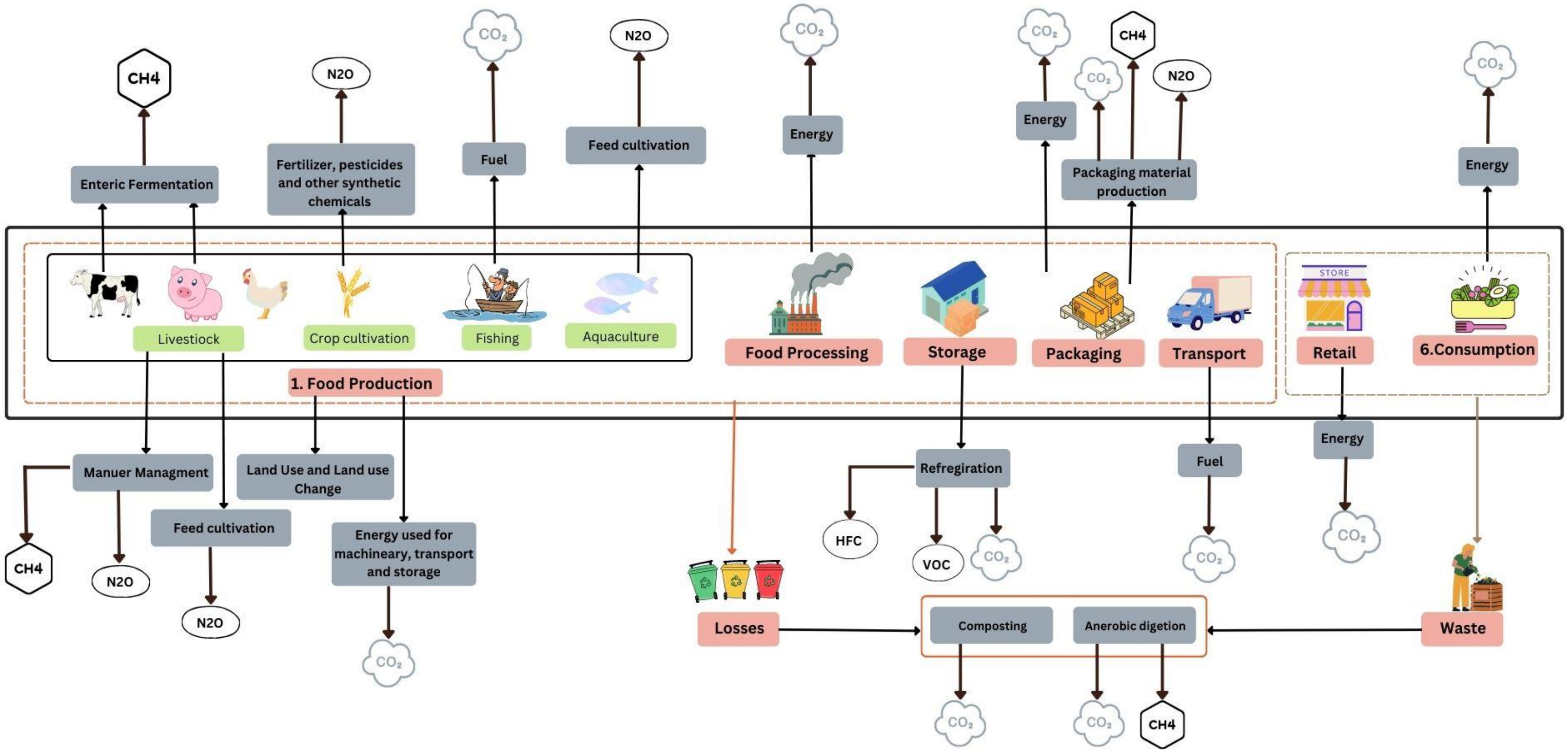

Figure 3. Emissions related to the food system.

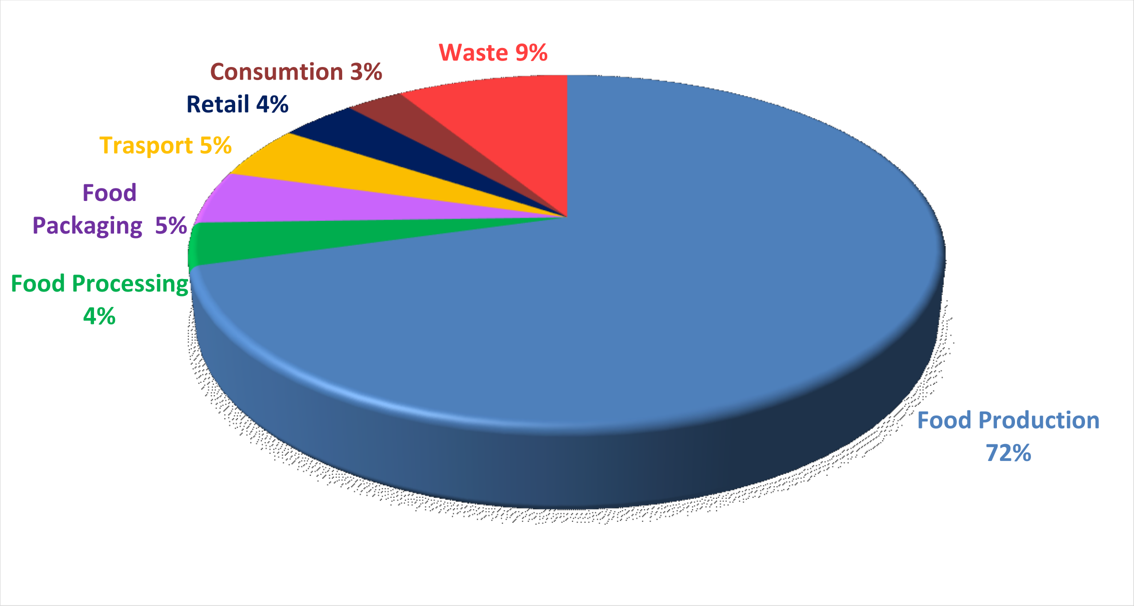

Figure 4. GHG emissions from the global food system in 2015 (Crippa et al. 2021; 2022).

3.2 Previous work on emissions and food carbon footprints

A number of studies have been done related to food CF in order to improve sustainability in food systems and diet planning which can result in climate mitigation.

Virtanen et al., (2011) conducted a study to evaluate the climate impacts of the food sector at both macro and micro levels. The macro-level assessment was carried out for the Finnish food chain using the Economic Input Output-Life Cycle Assessment approach. The findings showed that the Finnish food chain contributes 14% to climate change, with CO_2 emissions accounting for 40%, CH_4 emissions for 25%, and N_2O emissions for 34%. On an individual level, the study found that a single person contributes 7.7kg CO_2 eq /day. At the micro level, the study used the lunch plate approach, which included 30 different lunch portions with equal energy and nutrient contents, but with varying food combinations, for instance, vegetables, meat, dairy products, fruits, and nuts. The results showed that a single lunch plate accounts for 0.65-3.8kg CO2 eq. Moreover, homemade portions were found to have a lower impact than ready-to-eat products. Additionally, the study revealed that 70% of emissions occur during raw material processing at farming.(Virtanen et al. 2011)

In another study conducted by Baroni et al., 2007 the environmental impact of different dietary patterns was evaluated across various food production systems. The study compares different scenarios, including an omnivorous diet based on non-organic and organic farming, and a vegan and vegetarian diet with conventional and organic farming. The research findings indicated that a normal unbalanced diet has the highest environmental impact. The study also revealed that animal-based products have a greater environmental impact compared to plant-based products. Moreover, conventional farming was found to account for higher GHG emissions and other environmental impacts.(Baroni et al. 2007)

Food purchasing behaviours are important when studying the footprint of food. Meinilä et al. (2022) conducted research on food purchasing behaviour in the Finnish population. The annual purchasing data was collected through loyalty cards from S Group, which is one of the largest grocery chains in Finland. The relationship between purchasing patterns and the CF of product groups was calculated. The LCA method was used to analyse the relationship between the CF and the expenditures of consumers. They identified six food patterns to which all the products belong. Animal-based, Easy cooking, Ready to eat, High energy, Traditional, and Plant-based food. According to their calculations, animal-based food patterns account for the largest CF while plant-based for the lowest. In terms of monetary value, Traditional food patterns spent the least while animal-based, ready-to-eat, and plant-based food patterns consumed the highest. Further, animal-based, and easy cooking patterns accounts for the highest CF per euros spent.(Meinilä et al. 2022)

4 FINNISH FOOD SYSTEM

4.1 Food consumption

Finnish food consumption patterns are unique and varied which reflects the country's geography, climate, history, and culture similar to any other country in the world. Finnish food patterns are aggregated with surviving the harsh northern climate conditions. (Visit Finland 2022)

Oatmeal or oat porridge is a popular Finish breakfast often served with jam and berries. New potatoes with herring fish, fresh lake fish, or fish roe is another common finish food type.(Visit Finland 2022) Rice pies (karjalanpiirakka) are famous Finnish pastries with a rye crust, typically eaten for breakfast or as a snack, often paired with rice porridge and egg butter topping. Rye bread (ruisleipä) is a Finnish traditional food item that is dried into thin crisps and eaten as open-faced sandwiches and as snacks with butter. Bread cheese (leipäjuusto)is made with fresh cow milk. Usually, it is served with coffee or with cloudberry jam. Fish pie (Kalakukko) traditional Finnish dish made with rye flour, fish, pork, or bacon, and seasoned with salt. Cinnamon buns (korvapuusti) are traditional pastries served with coffee. The dough is made with milk, fresh yeast, and ground cinnamon. (Finnstyle 2022)

Fish is a common food in Finland, with fried vendace (muikku) being a popular dish of small fish fried in butter (Finnstyle 2022). Salmon soup, pickled baltic herring, and smoked vendace are other common Finnish fish dishes (Visit Finland 2022). Cured salmon (graavilohi) is a popular Nordic dish made by curing raw salmon in salt sugar and dill. It is often served as an appetizer with dill or mustard sauce on bread or with boiled potatoes.(Finnstyle 2022)

Additionally, the traditional Finnish diet has a great emphasis on the consumption of wild seasonal food products, for example, berries, mushrooms, rod fish, and ice fish. These foods are accessible to Finns without the need for permission from landowners.(Risku-Norja et al., 2008) Lingonberries, woodland strawberries, and blueberries are common in Finland cuisine. Cloudberry jam is made of berry season in the summer. (Visit Finland

2022) Blueberry pie (Mustikkapiirakka) is a common dish in the Nordic cousin which is served with yoghurt and fresh milk. Other seasonal berries including lingonberries can also be used for pies.(Finnstyle 2022). Sauteed reindeer (poronkaristys) is a common dish in Finland made of thin slices, fried in fat, spiced with salt and pepper, and cooked in water, cream, and beer. It is served with sugared lingonberries, mashed potatoes, and cucumber pickles. (Finnstyle 2022) Salty liquorice (salmiakki) is the most famous Finnish candy. It is a liquorice flavoured with ammonium chloride for a stringent salty taste. Ice-cream, alcoholic beverages, and meat are also flavoured with it. (Finnstyle 2022)

4.2 Finnish food consumption statistics

This section presents an overview of food consumption in Finland based on the data from the Natural Resource Institute Finland for the year 2021. The data shows that the consumption of food in Finland has remained relatively stable in recent years, with minor changes in individual varieties. Figure 5 shows the per capita consumption of different food items, including vegetables, fruits, meat, liquid milk products, cheese, eggs, fish, and cereals, in 2021. (Natural Resources Institute 2022a)

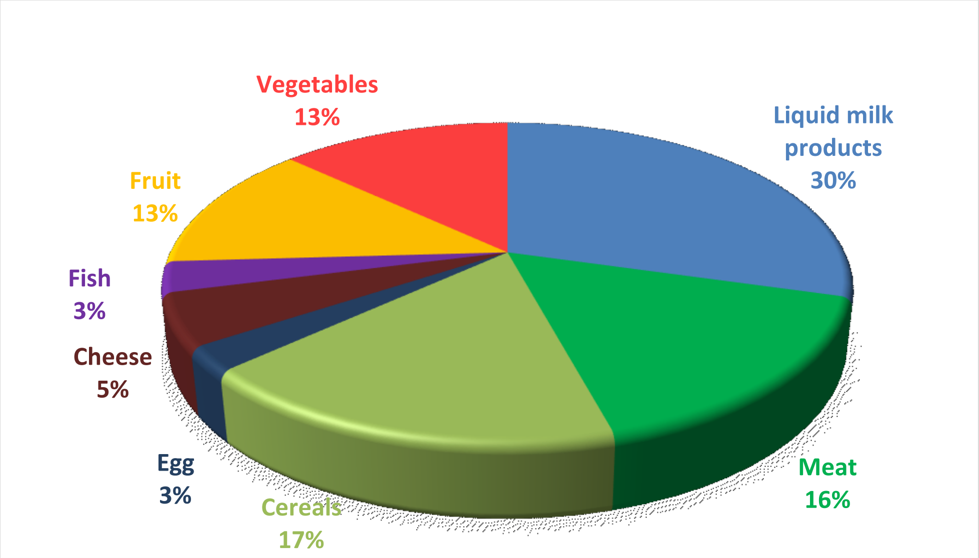

Figure 5. Per Capita food consumption of Finland 2021 based on (Natural Resources Institute 2022a).

The data reveals that liquid milk products were the most consumed food item, with an average consumption of 142 kg per capita per annum. Meanwhile, egg and fish consumption was the lowest, with an average consumption of 12 kg and 15 kg per capita per annum, respectively. (Natural Resources Institute 2022a)

Cereal consumption per capita in 2021 is shown in Figure 6. Wheat consumption remained the highest, accounting for 45.4 kg per capita, while barley had the lowest consumption rate of 0.9 kg per capita. Wheat and oat consumption have increased over the past two years, while rye consumption shows a slight decrease. Consumption of bread cereals including buckwheat and quinoa has increased comparatively.(Natural Resources Institute 2022b)

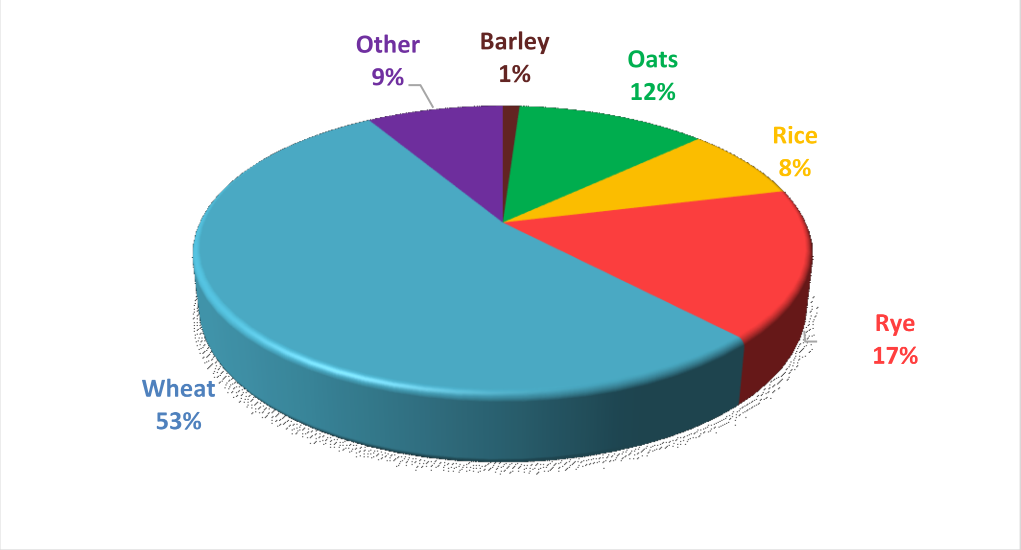

Figure 6. Per capita, cereal consumption of Finland 2021 based on (Natural Resources Institute 2022b).

Figure 7 illustrates the per capita consumption of meat in 2021. Total meat consumption has decreased compared to the previous year, with poultry consumption slightly increasing to 28.4 kg, which is only 0.5 kg lower than pork consumption. Pork and beef consumption have decreased, while mutton and other meats have remained the same over the last couple of years. (Natural Resources Institute 2022b)

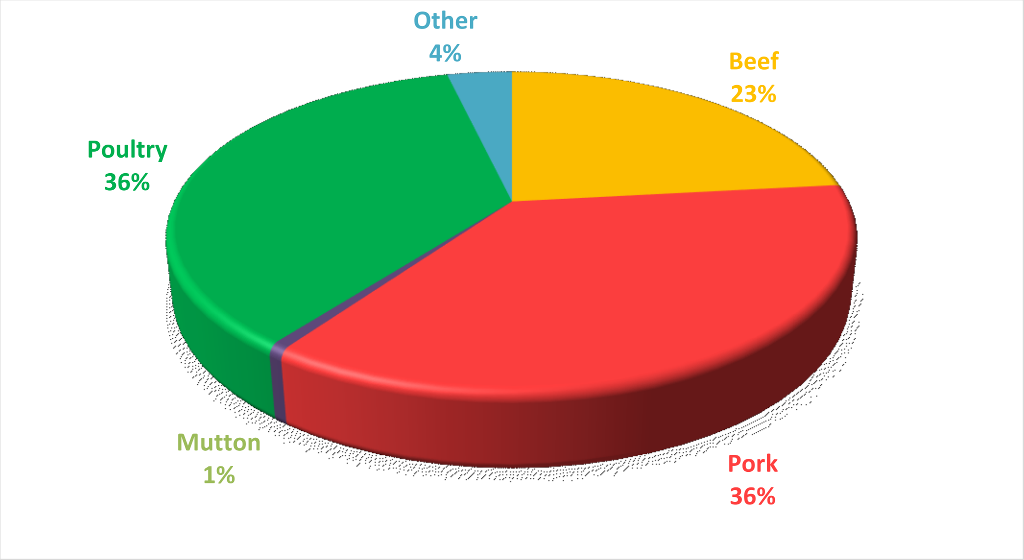

Figure 7. Per capita, meat consumption of Finland 2021 based on (Natural Resources Institute 2022b).

Furthermore, the data indicate that liquid milk consumption has been declining for several years, with a further slight decrease of 1.5% in 2021 compared to 2020. Liquid milk consumption was 96 kg per capita, with 57% of it being low-fat milk. Cheese consumption was 25.5 kg per capita, and egg consumption was 11.9 kg per capita. Fresh fruit consumption was 56 kg per capita in 2021, while fresh vegetable consumption was 62.6 kg per capita. (Natural Resources Institute 2022b)

In terms of fish consumption, the data reveals that each person consumed four kilos of domestic fish and over eight kilos of imported fish in 2021. The highest consumed domestic fish was rainbow trout, while the most popular imported fish was farmed salmon, followed by canned tuna and other tuna products, shrimp and shrimp products, Atlantic herring products, and frozen Pollock.(Natural Resources Institute 2022c)

The most consumed food type and per capita consumption for 2020 were calculated by Kortesoja et al. (2022). The study utilized data from various sources, including the Finnish Natural Resources Institute's statistics (Luke), Finnish customs statistics (Tullin tilastot), and consumption and import statistics from Ruokatieto (Ruokatiedon Tietohaarukka). The findings revealed that liquid milk, cereals, and meat were the top three food types in terms of per capita consumption, with individuals consuming 140 liters, 81 kilograms, and 79 kilograms, respectively. The fourth spot on the list was occupied by beer, with a per capita consumption of 68 liters. Fruits and vegetables followed closely behind, with individuals consuming 65 kilograms and 64 kilograms, respectively. Among the vegetables, banana is found as the most consumed fruit in Finland. Sugar consumption was 32 kilograms, while cheese consumption was 25 kilograms. Fish consumption was 15kg per capita. Eggs, and wine each had a consumption rate of 12 kilograms, with coffee coming in at 9 kilograms. Spirits and butter were at the bottom of the list, with a per capita consumption rate of 4 kilograms and 3 kilograms, respectively.(Kortesoja et al. 2022)

4.3 Food production

This provides an overview of the main agricultural productions in Finland, according to the statistics provided by Natural Resource Institute Finland.

Finland has a thriving food production industry, despite the harsh and long winter conditions. Agricultural productions include meat, dairy, crops, and fish. Horticulture is also involved in food production in Finland.

In 2022, the total meat production in Finland was 403 million kg, which is a 2% decrease from the previous year. The pork had the highest production followed by poultry, beef, lamb, and mutton. Beef and pork production fell slightly, while poultry meat production remained almost unchanged. (Natural Resources Institute 2022d)

The total cereal harvest in 2022 was 3.6 million tons, with barley being the most produced followed by oats, wheat, and rye. The organic cereal harvest accounted for 5% of the total harvest, and while there was a slight decrease in rye harvest, wheat, barley, and oats increased compared to 2021. Additionally, the potato harvest was 562,000 tons, while the pea harvest was 92,000 tons, indicating a comparative increase compared to the previous year (Natural Resources Institute 2022e)

During the crop year from 1 July 2021 to 30 June 2022, cereal production played a critical role in feed production. The total cereal production of 2208.4 million tons. 1730 million tons were used for feed production, while the remaining 478.4 million tons were used for human consumption. Barley was the most commonly used cereal for feed production. The data further revealed that 78% of the total cereal harvest was used for feed production, whereas nearly less than a third was used for human consumption.(Natural Resources Institute Finland 2022a, 2022b)

In 2022, egg production in Finland was around 76 million kilos, which is a 2% decrease from 2021. According to the statistics 55% of eggs were produced in barns, 33% in enriched cages, 8% in organic eggs, and 3% in free-range eggs.(OSF: Natural Resources Institute Finland 2023b) Barn eggs are produced in hen pens where the hens are allowed to move freely, while enriched cages are improved battery cages with more space and amenities. Organic eggs are produced from chickens that have been raised under organic conditions, free from synthetic fertilizers, pesticides, genetically modified organisms, hormones, and antibiotics. Free-range eggs come from hens that are allowed to roam outside and are given a normal hen life depending on the farm.

Total milk production in Finland has shown a marginal decline over the past five years. In 2022, the country's total milk production was 2193 million liters indicating an 8% decline compared to 2021. Approximately, 98% of this is utilized in dairy production including a range of products for instance, liquid milk, buttermilk cream curd milk yogurt butter, and cheese. The remaining 2% is allocated to farms (OSF: Natural Resources Institute Finland 2023a). Furthermore, organic milk production was reported as 81 million liters in 2022 which also experience a decrease compared to the previous years (OSF: Natural Resources Institute Finland 2023b)

The total fish production in 2021, which includes both marine and inland commercial, recreational, and fish production for food, reached 147,525 million kg. While marine fish production dominates inland production in terms of overall output, the contribution varies significantly among categories. Notably, commercial fishing remains the largest contributor to fish production, accounting for 102,375 million kg in total, with the majority (95%) coming from marine sources, including baltic herring and sprat. (Natural Resources Institute 2021)

The largest share of fish production is coming from natural fish stocks in the Baltic Sea. However, commercial marine fish production has been declining over the last five years. In contrast, the recreational fish production sector, also known as game fishing, has seen improvement over the same period, reaching 30,751 million kg, with more than 80% of the catch coming from inland sources. The food fish production sector, consisting of fish bred for consumption in tanks or artificial enclosures, accounted for 14,399 million kg, with marine fish (rainbow trout) representing 79% of the total output. Notably, food fish production has remained relatively stable over recent years. Overall, these findings highlight the importance of sustainable fishing practices and the effective management of fish resources to ensure the long-term viability of the fishing industry. (Natural Resources Institute 2021)

The utilized agricultural area has not changed notably during the past decade; however, each category alone has fluctuated. 2 268 000 hectares of land was used for agriculture in Finland in 2022. 54% of it was utilized for Feed production while 33% for livestock and 13% for other crops including cereal for human consumption, potato, and other vegetables (Natural Resources Institute 2022f)

Horticulture is an essential contributor to Finnish food production, with a diverse range of vegetables, fruits, and berries being cultivated both in open areas and greenhouses. In 2022, the outdoor production of horticultural crops amounted to 189 million kg, with carrots being the highest-yielding crop at 76 million kg. Other notable outdoor crops included white and savoy cabbage, onions, and garden peas. The production of berries in 2022 amounted to 19,715 kg, with strawberries being the highest-yielding variety. Among outdoor fruits, the yield of apples was the largest. (OSF: Natural Resources Institute Finland 2022a) In terms of greenhouse production, the total vegetable yield in 2022 is 89 million kgs with cucumber being the highest, 49 million kg. Tomatoes, special tomatoes, cabbages, and other vegetables were also significant contributors to greenhouse production. (OSF: Natural Resources Institute Finland 2022b). The total land area utilized for outdoor and greenhouse cultivation in 2022 was 18,716 hectares and 362 hectares, respectively (OSF: Natural Resources Institute Finland 2022c).

4.4 Food Imports

This section provides an in-depth overview of Finnish food-related imports, as per the Natural Resource Institute of Finland. Agricultural imports increased by over 4% in 2021 compared to the previous year. The major importing countries for Finland include the Netherlands, Germany, Sweden, Spain, and Russia (Natural Resources Institute 2022g)

The Netherlands primarily exports technical fats and oils, propagating material for horticulture crops, animal fats, sugar confectionery, chocolate, feed, and beverages to Finland. Bakery products, feed, and cheese are major imports from Germany. Sweden exports bakery products, sugar confectionery, and processed food products, while Spain mainly exports fruit, vegetables, and alcoholic beverages. Feed, feed material, frozen vegetables, mushrooms, berries, alcoholic beverages, and reindeer meat is imported from Russia and salmon from Norway. (Natural Resources Institute 2022g)

In 2021, Finland imported 46,714 tons of meat with poultry being the highest followed by pork, beef, and other meat. Poland and Germany are notable poultry exporters, while Germany is the largest pork exporter. Beef is primarily imported from Poland, Ireland, and the Netherlands. (Natural Resources Institute Finland 2022c)

Finland imported 195,000 million kg of cereal in 2021. However, oats, wheat, and rye imports are insignificant compared to their production. Barley was imported mainly from Estonia and Germany. Maize was imported from Poland, and rice, which totalled 11,000 million kg, was mainly imported from Italy, followed by Spain and Thailand. (Natural Resources Institute Finland 2022c)

Fruits, berries, and vegetables take up a vital import fraction, with 495,677 tons being imported in 2021. Finland's notable berry exporters are Poland, Sweden, the Netherlands, and Germany, including strawberries, raspberries, and other berries, both fresh and frozen. In terms of widely consumed fruits and vegetables, Finland primarily imports apples from Poland, Sweden, and the Netherlands. Banana is identified as the most consumed fruit in Finland (Kortesoja et al. 2022), with a total of around 111,000 tons imported annually. Bananas are mainly imported from South and Central America, with the largest exporter being Costa Rica, followed by Panama and Ecuador. Citrus fruits are mainly imported from Spain, while other countries exporting citrus fruits to Finland include South Africa and Egypt. (Natural Resources Institute Finland 2022c).

The Netherlands is a significant exporter of Finland being notable for exporting several vegetables, including onion, cucumber, tomato, and sweet pepper. potatoes are imported from Sweden. Belgium is significant for exporting frozen vegetables and mushrooms to Finland. Lettuce, cabbage, and carrot are imported from Spain while Italy is the primary exporter of carrots. Soybeans are imported from Poland while Peas and other legumes, fresh are from Belgium. (Natural Resources Institute Finland 2022c). Soybean was imported from Brazil for a long time, however, due to the trade restrictions imports were terminated after 2018(Karlsson et al. 2021).

In 2021, 111,273 tons of milk and dairy products were imported, with significant exporters being Germany, Sweden, Denmark, Netherlands, and France. Denmark, Germany, and the Netherlands are the most significant cheese exporters. Liquid milk is imported primarily from Sweden and Germany, while poultry eggs are mostly imported from Sweden.(Natural Resources Institute Finland 2022c)

In 2022, Finland imported a total of 3.1 million metric tons of coffee. The largest coffee and tea exporters to Finland in 2022 were Brazil, Colombia, and Honduras (Natural Resources Institute Finland 2022c). Unroasted coffee is the most imported coffee variety, and it undergoes final processing in Finland before it is ready for consumption (Kahvi- ja Paahtimoyhdistys 2021)

4.5 The biodiversity effects of Finnish food consumption (local and global)

The food system of Finland has a significant impact on biodiversity. Conversion of natural habitats to agricultural land, unsustainable agricultural practices, pesticides, and fertilizer usage, and impacts from livestock are among the major threats. Some impacts for instance land use change are less significant in Finland due to its lower biodiversity compared to the regions near the tropics (Loiseau et al. 2020). However, eutrophication is a significant impact in Finland due to the catchment area of the Baltic Sea being affected by agricultural activities (Loiseau et al. 2020).

Kortesoja et al. (2022) identified the ten most consumed food types in Finland that have the highest impact on biodiversity. Liquid milk and milk products, wheat, broiler (egg and poultry), bananas, tomatoes, fish, coffee, palm oil, rice, and pea are among these ten.

Liquid milk and milk production-related significant biodiversity threats in Finland are caused primarily by manure management which results in deforestation due to the utilization of arable areas, and nutrient loading to water bodies. Wheat is the next most consumed food type which takes 20% of land acquired for cereal cultivation. The impacts of wheat cultivation on biodiversity are found as loss of habitats due to cultivation, impacts from fertilizers and pesticides due to nutrient loading, and soil compacting effects of mechanical tillage. (Kortesoja et al. 2022)

Poultry and egg are other highly consumed food types, where 40% of impacts are coming from feed cultivation, specifically soybean cultivation. 95% of soybean imported to Finland is used for feed production(Karlsson et al. 2021). Brazil was the major soybean exporter to Finland, however, due to the global trade policy changes in 2018, north America become the largest exporter. Thereby, Finland is not contributed to the significant impacts of soy cultivation in Brazil and other South American (Karlsson et al. 2021). The remaining major impacts of broilers are eutrophication due to manure management and feed cultivation.(Kortesoja et al. 2022)

Bananas which are the mostly consumed fruit in Finland are imported from Central and South America. Most bananas are cultivated in cleared rainforest areas; thus deforestation is the main threat associated. Other impacts are excessive use of pesticides, soil erosion and soil improvement, and leaching of nutrients and harmful substances into water ways and waste.(Kortesoja et al. 2022) Further, washing and packaging of collected bananas have a significant impact on biodiversity (Roibás et al. 2015).

Tomatoes are cultivated in green houses in Finland and some percentage is imported. Greenhouse tomato production has a lesser impact compared to the tomatoes grown on land. However, energy consumption is significant if a non-renewable source is utilized. (Kortesoja et al. 2022) The CF for greenhouse-produced tomatoes (including special tomatoes) in the year 2013 in Finland was 3.0 kgCO2-eq/kg tomatoes where 68% account for energy, 26% for electricity, and the rest were other emissions (Silvenius et al. 2019).

Fish is another food type of the most consumed food. Fishing has impacts on biodiversity in relation to its fishing method. Further, specifically in Finland eutrophication is caused by nutrient loading to the Baltic Sea. However, prevailing farming methods and feed are improved greatly. Nutrient loading has decreased compared to the levels in the 1990s. Further, Norway, where Finland imports most salmon fish, has significant biodiversity threats due to fish disease and the interbreeding of genetically weak salmon with natural salmons. On the other hand, in Finland, the main farmed fish species is the rainbow trout which cannot interbreed with native species under Finnish climate conditions.(Kortesoja et al. 2022)

Coffee is another one of the mostly consumed foods in Finland. Coffee production is done in South America and South Asia. Colombia is one of the top coffee exporters of Finland for more than two decades (Natural Resources Institute Finland 2022c), which is one of the countries with the highest number of threatened species due to coffee imports (Lenzen et al. 2012). Land use change impacts from monoculture farming, soil erosion, and nutrient loading to water ways are major biodiversity threats due to coffee cultivation. These impacts depend on various factors including species cultivated, cultivation practices, and the structure of the plantation.(Kortesoja et al. 2022)

Palm oil, which is next on the list, is cultivated in Southeast Asia. It is used for the production of margarine, pastries, biscuits, ready-made meals, and sauce ingredients.(Kortesoja et al. 2022) Although palm oil production has sustainability criteria and certifications to protect biodiversity, indirect land use related to palm oil cultivation is not covered. Conversion of pasture and forests due to palm oil cultivation is not identified. Palm oil plants are following monoculture farming and thus result in soil impoverishment and erosion. Habitat destruction and tropical swamp drying are other impacts (Meijaard et al. 2018).

Rice has biodiversity impacts due to the vast deforestation and unsustainable farming practices. However, it also provides ecosystem services for wetland species adapted to rice fields. Mechanical tillage, inorganic fertilizer, and pesticide utilization negatively damage the environment.(Kortesoja et al. 2022).

In Finland, the conversion of peatlands to agricultural land has led to significant biodiversity loss, as peatlands are important habitats for many species (Fraixedas et al. 2017). Peatlands are unique ecosystems that support a variety of plant and animal species, and these species are well adapted to the wet, acidic conditions found in peatlands. In addition to direct habitat loss, the drainage of peatlands can also lead to soil degradation, erosion, and water pollution, further impacting biodiversity.(Joosten and Clarke 2002)

Moreover, Finland potentially contributes to the extinction footprints of the countries of origin of its imported goods. Costa Rica, Brazil, Colombia, Ecuador, and Peru are among the food importing countries to Finland (Natural Resources Institute Finland 2022c), named as countries with the highest extinction footprints due to exports (Irwin et al. 2022).

4.5.1 Baltic Sea

The Finnish agricultural and food system has a significant impact on the Baltic Sea due to the high levels of nutrient runoff and pollution caused by agricultural practices. The Baltic Sea near Finland includes the Bothnian Bay, the Bothnian sea, and the Gulf of Finland.

Eutrophication in the Baltic Sea is a controversial biodiversity issue where more than 97% of the sea is impacted from 2011–2016. Agriculture accounts for 70% of phosphorous loading and 60% of nitrogen loading to the Baltic Sea (HELCOM 2018). Excessive utilization of fertilizer, thus nutrient loading to the Baltic Sea from agricultural runoffs results in eutrophication. Eutrophication leads to the overgrowth of algae, which can deplete oxygen levels in the water, resulting in dead zones and negatively impacting marine life. Soil erosion is one way of nutrient loading on the Baltic Sea. Intensive farming practices, such as ploughing and drainage, can increase soil erosion, resulting in sedimentation in rivers which ultimately reaches the Baltic Sea. The sedimentation can adversely affect water clarity and light penetration, which are vital for the survival of underwater plants and animals.(HELCOM 2018)

4.6 Food waste management in Finland

Waste management of households and communal activities are the responsibility of local municipal authorities (Ministry of the Environment 2011). In municipal waste, food waste is included in both biowaste and mixed waste (Silvennoinen 2020). Total municipal waste generated in 2021 was 830,673 tons, mixed waste accounted for 1,720,691 tons, and biodegradable waste for 465,178 tons. (Waste statistics and Statistics Finland 2022)

Municipal waste treatment methods available in Finland are material recovery, without aerobic and anaerobic digestion, aerobic and anaerobic digestion, energy recovery, incineration without energy recovery and landfilling, and other disposal. Biowaste and the mixed waste amounts going for incineration without energy recovery, as well as landfilling, and other disposal methods are comparatively insignificant. 98% of mixed waste goes for energy recovery. Around 83% of biowaste goes for aerobic and anaerobic digestion while around 4.5 % and 11% end up in material recovery, without aerobic and anaerobic digestion and energy recovery respectively. (Waste statistics and Statistics Finland 2022)

According to a study conducted by Silvennoinen (2022), the average annual food waste per person in Finland is 23kg. The average food waste generated in a year is between 385 and 485 million kg, which is 15% of the total amount of food consumed in Finland. 19% of food waste is vegetables, 18% is home-made cooked food and 15% is milk products. Major reasons are stated as spoilage, expiration, and plate leftovers. 40% of the food is wasted without spoiling. The same study shows that the retail sector in Finland generates 65-75 million kgs of food waste per annum. In the industries, 75- 140 million kg of edible food is wasted.(Silvennoinen 2020)

5.CARBON FOOTPRINT CALCULATION AT THE UNIVERSITY OF OULU

Carbon Footprint Working Group (CFWG) aims to address the climate mitigation strategies of the University of Oulu. The assessment of carbon footprint at the organizational level has emerged as a crucial tool for analyzing and mitigating carbon emissions. CFWG actively engages in calculating carbon footprint to achieve the goal of reducing carbon emissions by 50% compared to the level of 2019. The carbon footprint of the University of Oulu has been calculated since 2018. Several research studies were conducted sectoral-wise as necessary in order to achieve carbon neutrality and sustainability goals.

5.1 Carbon footprint in 2021

The university's CF consists of different categories, including electricity consumption, heating, restaurant services, business travel, procurement, research and laboratory equipment, commuting, direct fuel combustion, and property management. For the purpose of this thesis, the focus will be placed on the analysis of the carbon emissions associated with restaurant services, which accounted for 6% of the total CF in 2021. Following figure 8 depicts the contribution of different categories to the CF.

The primary objective of this thesis is to calculate the CF specifically associated with restaurant services at the University of Oulu for the year 2022, as part of the overall CF calculation for that year. Within the university, two main restaurant providers, namely Uniresta and Juvenes, are available. The analysis will focus on quantifying the carbon emissions associated with these providers' food supply order details to gain a comprehensive understanding of their environmental impact.

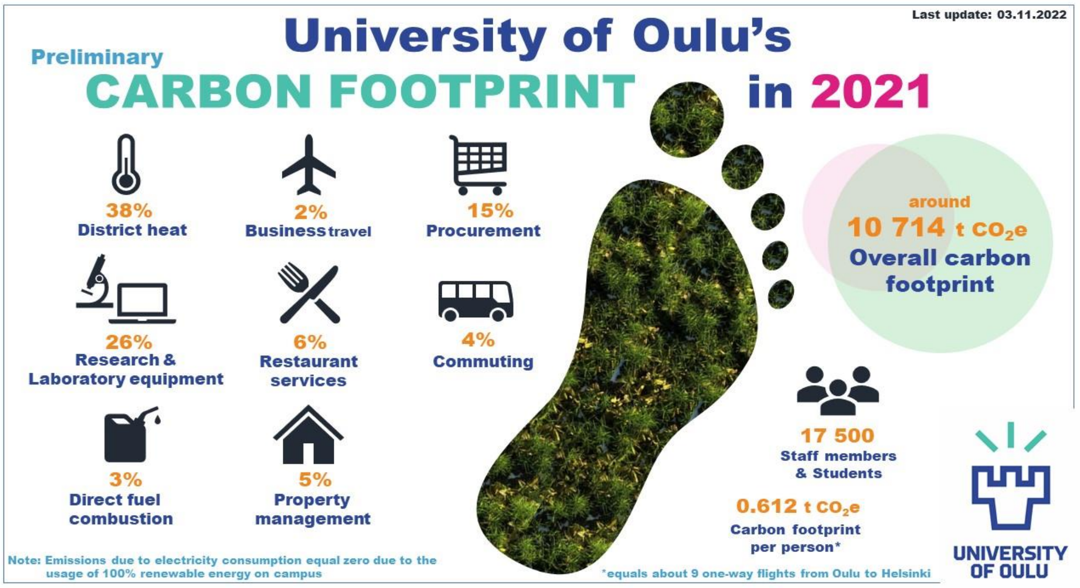

Figure 8. The carbon footprint of the University of Oulu in 2021.

5.2 University Restaurants

Uniresta operates two restaurants at the university: Kastari (Ravintola Kastari) and Kastari's cabinet located in the Linnanmaa campus and Medisiina (Ravintola Medisiina) in the main building of the Faculty of Medicine in Kontinkangas campus.

100 customer seats are available restaurant in Kastari and the 30 customer seats are in the Kastari cabinet. The restaurant Medisiina provides 306 customer seats, and the coffee shop provides 44 customer seats. Both restaurants provide lunch and catering services for special events depending on the requirement.

Juvenes operates a total of nine restaurants, namely Mara, Foodoo, Foodoo Garden, Napa, Café Hub, Café and Juice Bar, Tellus, Foobar, and Kylymä. The map of these restaurants is shown in Figure 9. Café Tellus is temporarily closed. These establishments offer a range of lunch options, café products, and catering services for special events.

Restaurant Mara located at the University of Applied Sciences (OAMK), offers 146 customer seats and a cabinet suitable for 40 people. Foodoo Restaurant, situated near the University's library, accommodates around 300 customers and provides a variety of sweet and savoury confectionery items. Foodoo Garden provides a picturesque setting with around 500 seats and a separate café area. Napa accommodates around 350 customers.

Café Hub provides 90 seats and serves breakfast, coffee, and a salad and soup lunch. Café and Juice Bar specialize in serving refreshing smoothies, juices, and coffee. Foobar offers 40 cabinet seats and a menu that includes hamburgers, pizza, and other snacks. Lastly, Kylymä caters to 100 customers and offers diverse lunch options alongside other café products.

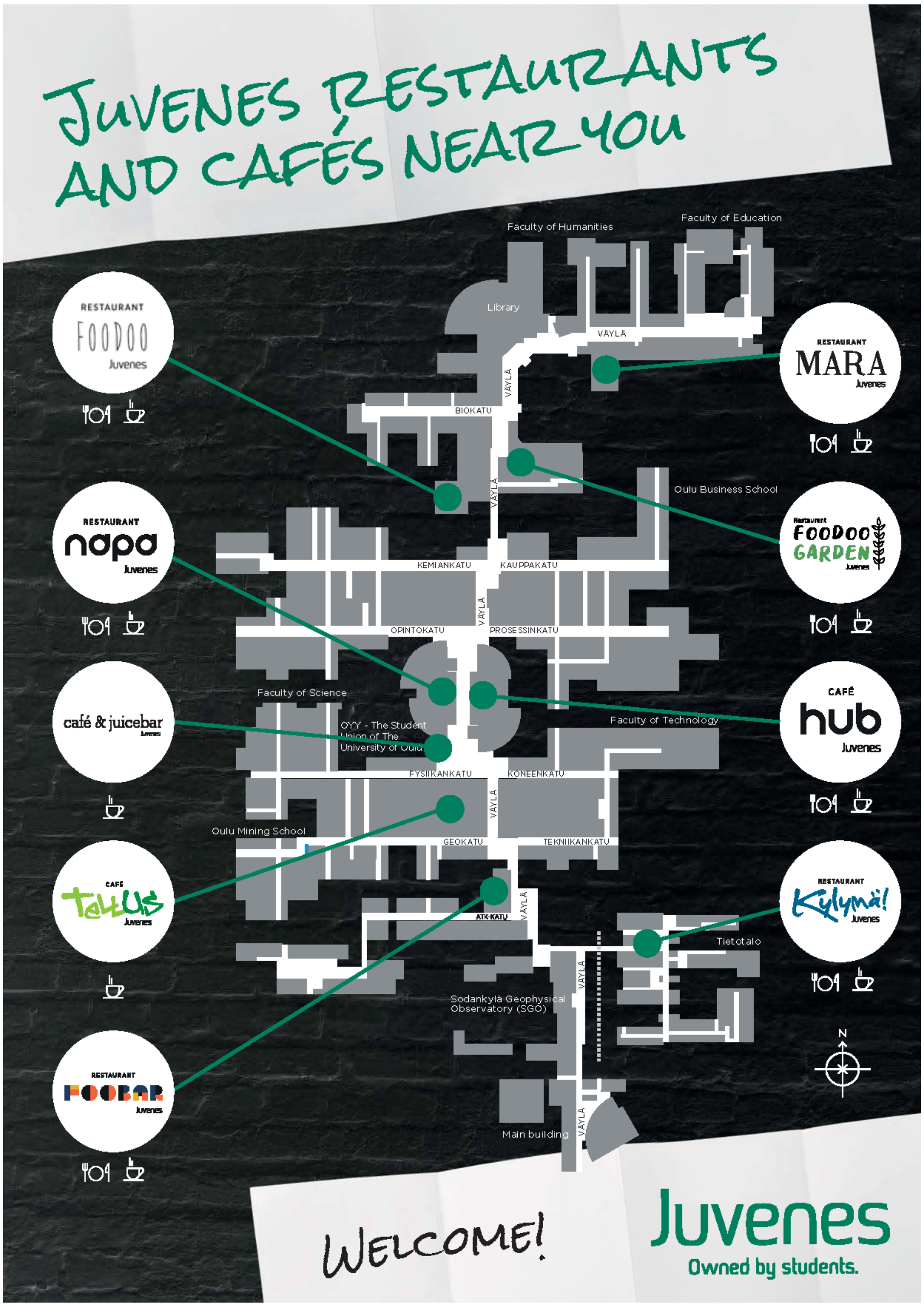

Figure 9. Juvenes Restaurants in Linnanmaa Campus (Juvenes, 2023)

5.3. Calculation of carbon footprint of food

The calculations for carbon emissions are based on purchasing details for the year 2022, obtained from restaurant service providers i.e., Uniresta and Juvenes. Electricity/energy, water, and heating utilized in the restaurants are not included in the calculation since those are considered for the university's total CF.

Latva-Hakuni (2020), identified 13 major food categories and a total of 97 sub-food categories. These major categories include vegetables, fruits and berries, cereals and side dishes, meat and eggs, fish, milk products, plant proteins, plant-based milk products, oils, sweets, spices, ready products, and beverages. To analyse purchasing documents and calculate emissions, food items are grouped into these food categories.

Moreover, Latva-Hakuni (2020) calculated emission factors by referring to various national and international literature published within the past ten years (see appendix 1). These emission factors consider the cradle to retail, which is from all the activities from primary production to retail.

Food waste generated during preparation and plate leftovers at restaurants are not taken into account in these emission factors. The restaurant food waste is disposed of as mixed waste and biowaste. Emissions related to different waste categories were calculated by Dahlbo et al. (2011). Mixed waste that goes to incineration accounts for 410 kgCO2eq / ton of waste and biowaste accounts for 60 kgCO2eq/ton of waste. (Dahlbo et al. 2011).

6 CARBON FOOTPRINT CALCULATION RESULTS

This chapter provides an analysis of the calculated CF results for the food services at the University of Oulu. It explores the contribution of different food categories to the overall CF.

The CF of the University of Oulu's food services in 2022 was calculated to be 770.17 tCO2eq. Among the service providers, Uniresta accounted for 270.04 tCO2eq, while Juvenes had a footprint of 500.13 tCO2eq. This value represents an increase compared to the food CF in 2021, which constituted approximately 6% of the university's total CF, amounting to approximately 643 tCO_2eq.

Table 1 presents the purchasing amounts and percentages, respective emissions/CF, and percentage contributions of food types (as discussed in Chapter 5.3). Notably, the most significant contributors to the CF are meat and egg followed by milk products, vegetables, and fish. The contribution of various food categories to the university's food CF is visualized in figure 10. Further, the analysis of the food purchasing data reveals that the highest-purchased food category is vegetables, followed by milk products, cereals, meat, and fish, as shown in Figure 11.

Although meat and egg are the fourth most purchased category, they contribute to the CF the highest, being responsible for 40.5% of emissions, equivalent to emitting 312tCO2eq. Alternatively, cereals and side dishes contribute 21% of purchasing total being the third most however contribute only 5.87% to the CF.

Table 1. Food purchased amounts and emissions of restaurant services at the University of Oulu.

Food Category	Purchased amount/kg	Share of purchased amount/ %	CF/ tCO_2eq	Share of CF / %
Meat and eggs	30673.10	9.11	312.715	40.45
Milk products	73461.51	21.82	139.81	18.08
Vegetables	78036.00	23.18	88.16	11.40
Finished products	20568.00	6.53	59.68	8.18
Fish	16140.00	4.79	56.34	7.29
Cereals and side dishes	70446.00	21.00	45.42	5.87
Beverages	8742.02	2.60	21.20	2.74
Fruits and berries	11763.00	3.49	11.60	1.50
Plant proteins	7070.00	2.10	10.73	1.39
Plant-based milk products	9253.00	2.75	8.4	1.09
Oils	2800.00	0.83	7.65	0.99
Sweets	2906.00	0.86	5.19	0.67
Spices	3407.00	1.01	2.68	0.35
Waste	9620.189115 (Generated amount)	2.78	0.58	0.07

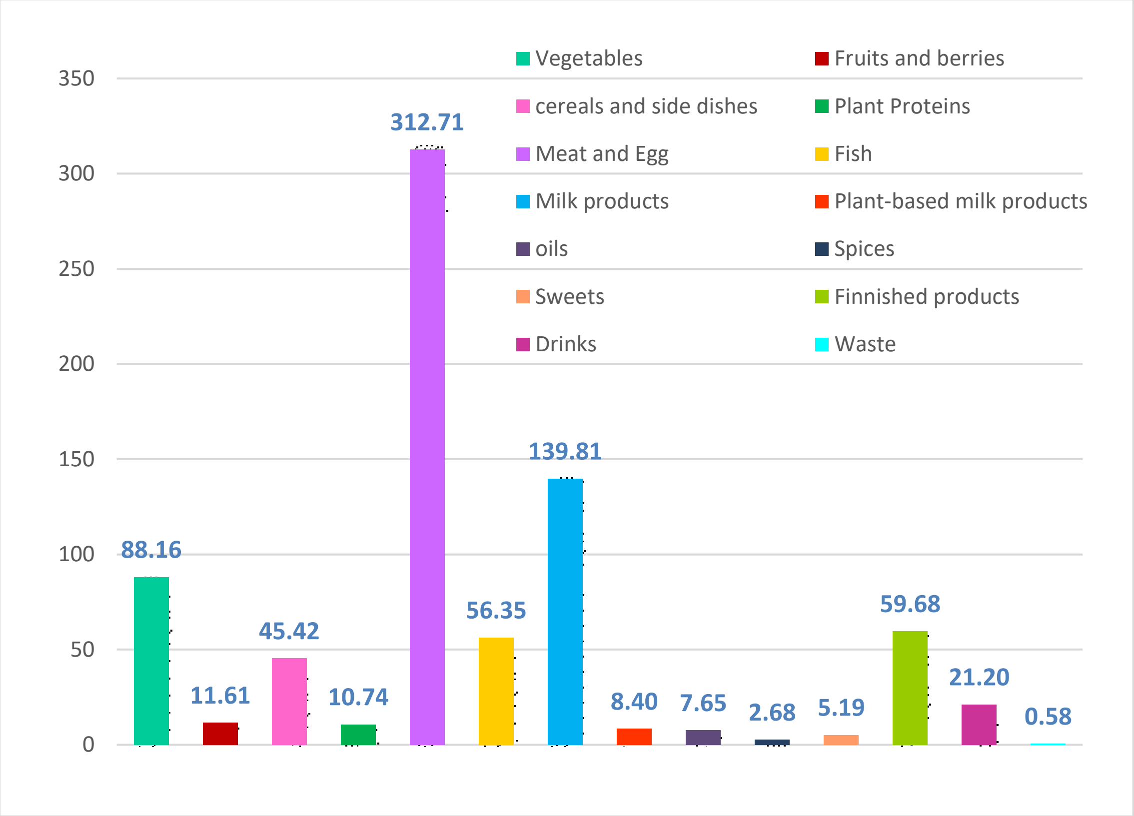

Figure 10. Emission shares from different food categories to the CF (tCO_2eq).

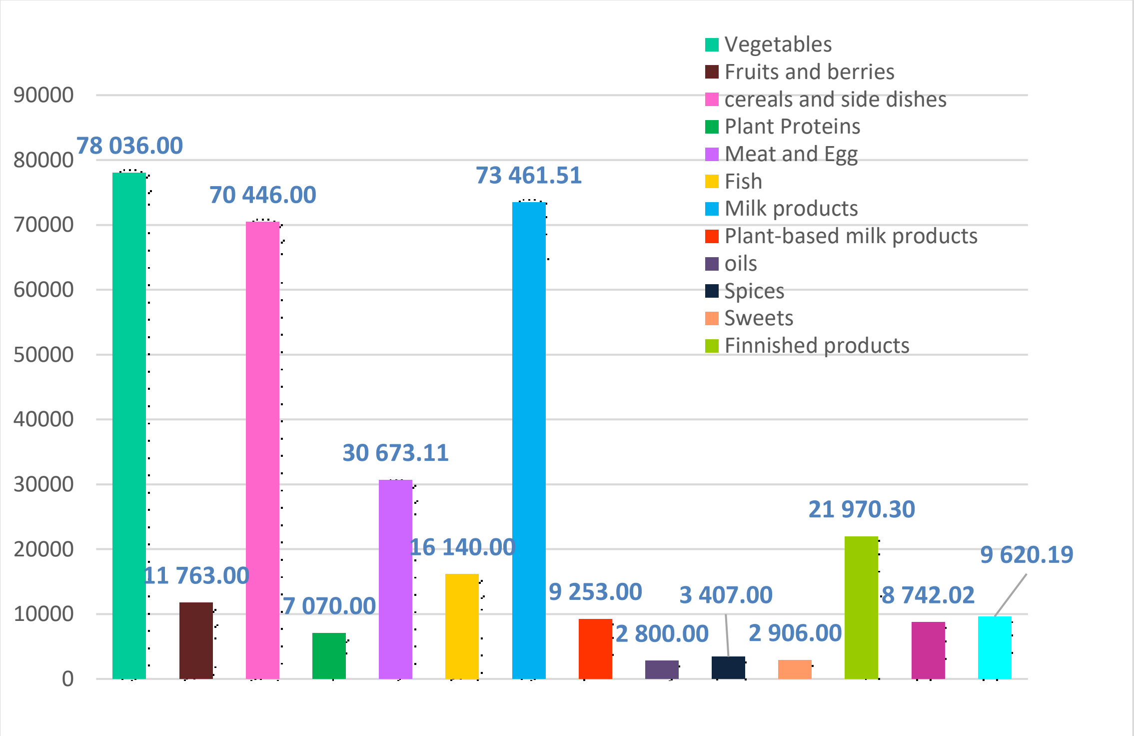

Figure 11. The purchased food shares in different food categories (kg).

6.1.1 Meat and egg

The highest contribution of the CF is coming from meat and egg which in total 312.71tCO_2eq. The total weight of meat and egg purchases is 30,673.10 kg, accounting for 9% of the total food purchases (Table 1).

The meat varieties include broiler, egg, beef, pork, game meat, processed meat, and meat combinations. Figure 12 illustrates the share of each subcategory in the total emissions of the meat and egg category, while Figure 13 shows the percentage of each purchased food type. Processed meat is the most purchased subcategory, but beef accounts for the highest emissions. Broiler contributes only 12% to the CF while accounting for nearly a quarter of the meat and egg purchases.

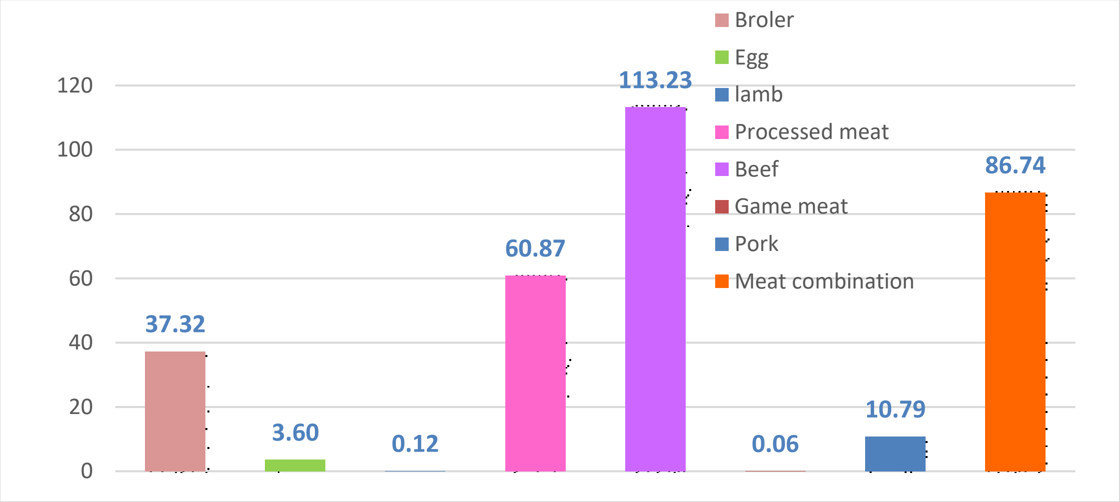

Figure 12.Emissions share of meat and egg category (tCO_2eq).

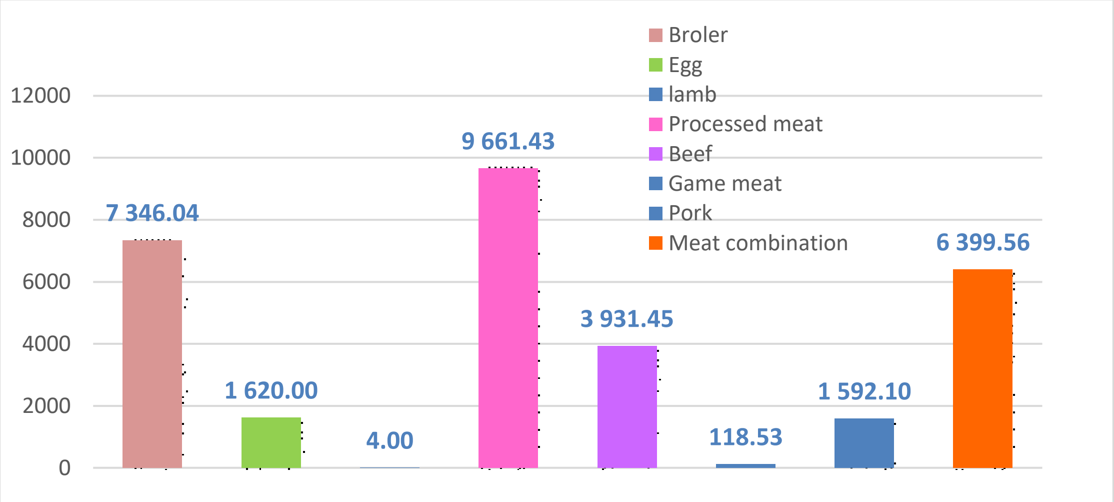

Figure 13. Share of purchased amounts of meat and egg category (kg).

6.1.2 Milk products

Milk products contribute 18.08% to the CF, making it the second-highest contributor. The total CF of milk products amounts to 139.81 tCO2eq. A total of 73,461.51 kg of milk products were purchased, which accounts for 21.82% of the total purchases.

The subcategories include liquid milk, common dairy products, cheese, butter, vegetable fat mixtures, and yogurt. Figure 14 illustrates the contribution of each subcategory to the CF of milk products, while Figure 15 shows the percentage share of each milk product category in the purchases.

Liquid milk contributes the most to the emissions at 29%, followed by cheese, common dairy products, and cream. In terms of purchasing share, liquid milk represents more than half of the total, while cheese and cream account for 5% and 6% respectively.

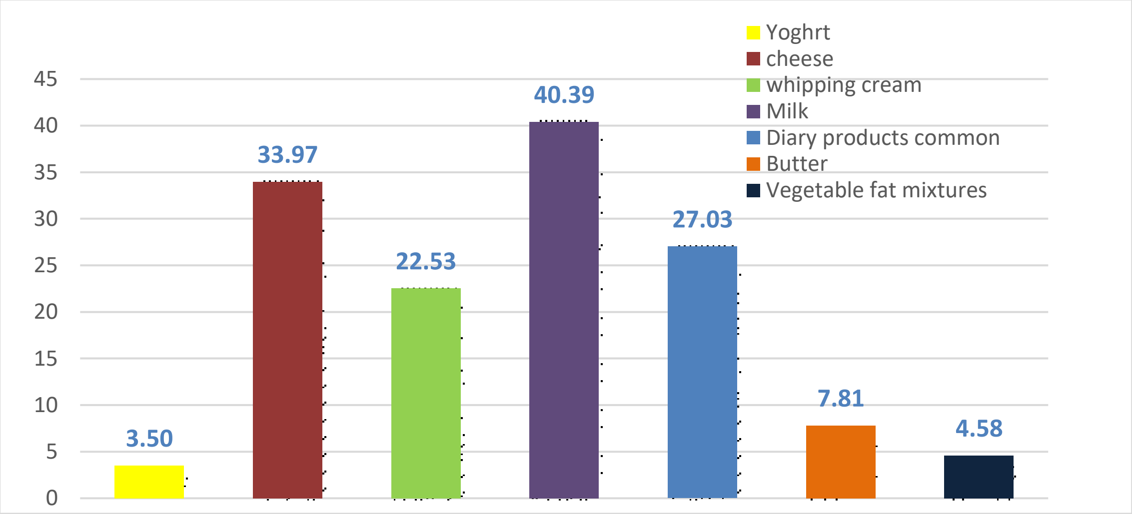

Figure 14. Emissions share of milk products (tCO_2eq).

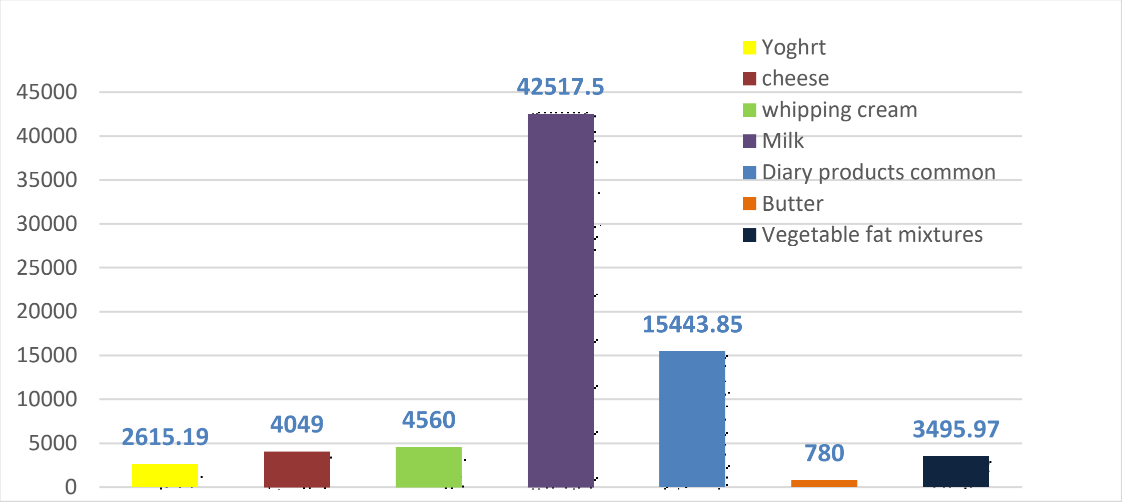

Figure 15. Purchasing percentages of milk products (kg).

6.1.3 Vegetables

Vegetables account for 88.16 tCO2eq of emissions, representing 11.40% of the CF. However, vegetables are the most purchased food item, with a total weight of 78,036 kg, accounting for 23% of the total purchases.

When analysing the emissions related to vegetable categories, it becomes evident that unspecified vegetables/vegetables in common have the highest share in the CF, accounting for 35.65% of emissions. This is followed by domestic cucumber and domestic tomato. Figure 16 illustrates the distribution of emissions across different vegetable categories.

Figure 23 presents the percentage distribution of vegetable purchases. Notably, although root vegetables are the second most commonly purchased type of vegetable, their contribution to the CF is only 6%. On the other hand, domestic cucumber, which accounts for nearly a quarter of the CF, represents 14% of the total vegetable purchases.

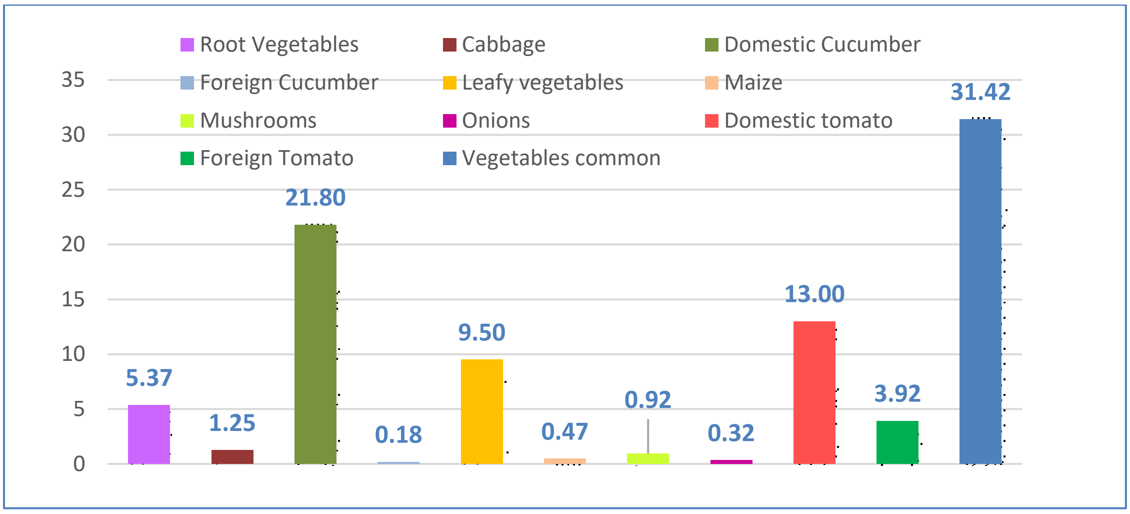

Figure 16. Emission percentages of vegetables (tCO_2eq).

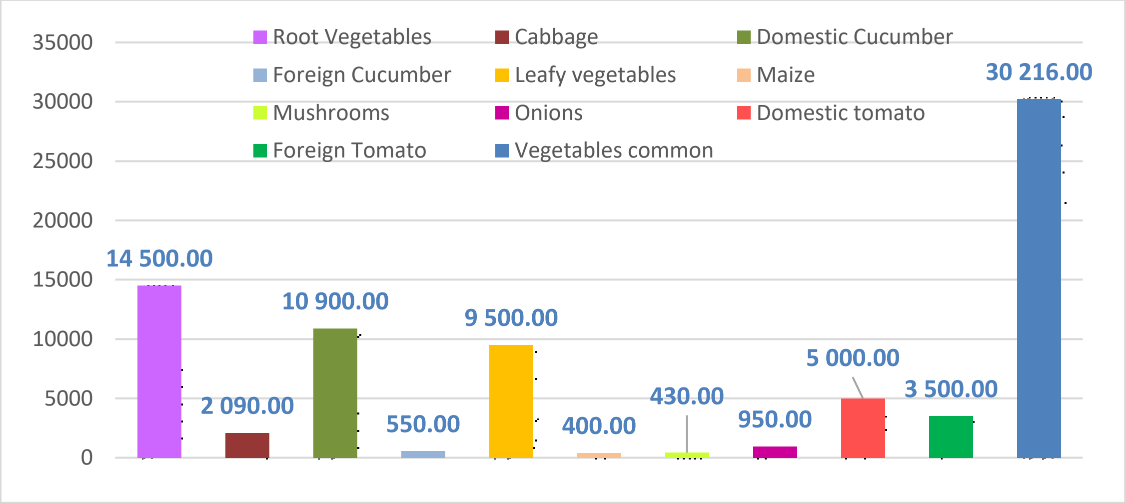

Figure 17. Purchasing percentages of vegetable categories (kg).

6.1.4 Ready products

The fourth on the carbon emissions list was finished products, which contributed 8.2% of the total. The total carbon emissions from finished products amount to 59.68 tCO_2eq. Figure 18 visualizes the contribution of each sub-category to the total emissions.

When considering the purchasing share of finished products, they account for nearly 6.53% of the total food purchases, with a total weight of 20,580 kg. Figure 19 illustrates the distribution of purchasing among different finished product categories.

Among the finished products, meat-based ready products have the highest emissions, accounting for 40% of the total, despite being the fourth most purchased category. On the other hand, fish-based products, although being the highest purchased finished food type at 24.65% of the total, are responsible for the second highest emissions.

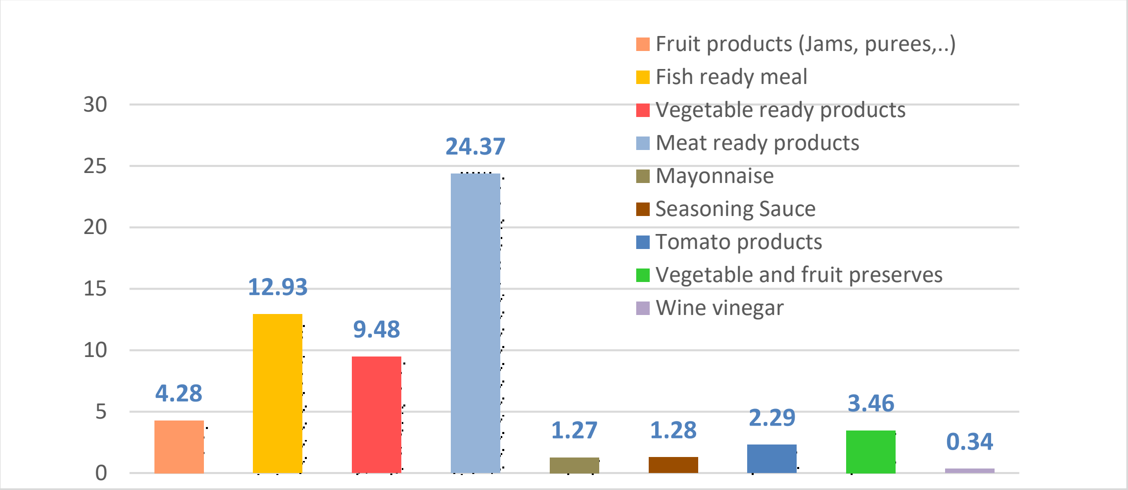

Figure 18. Emission percentages of finished products (tCO_2eq).

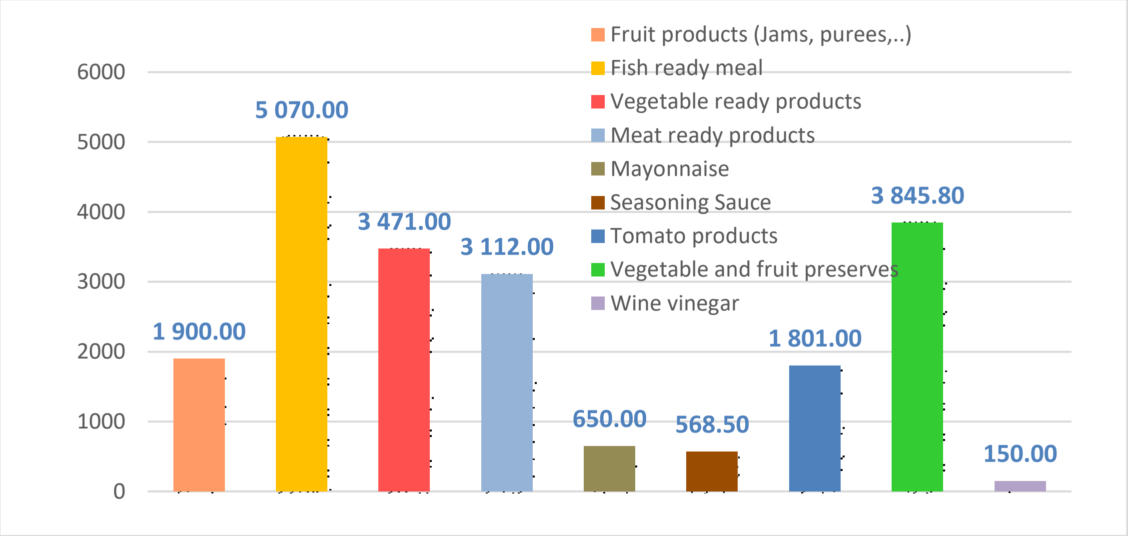

Figure 19. Purchasing percentages of finished products categories (kg).

6.1.5 Fish

The fish category accounts for 7.3% of total carbon emissions, responsible for emitting 56.34tCO2eq. In terms of purchases, fish represents 4.8% of the total weight, with a total of 161,140 kg. Figure 20 provides a visual representation of the contribution of different fish varieties to carbon emissions. The most commonly purchased fish category is common fish, which also contributes the highest emissions. Additionally, salmon and sati (a marine fish variety) are notable contributors to the CF. Although shrimp constitutes only 1% of the total purchases, it accounts for 4.7% of the emissions. Figure 21 illustrates the percentage distribution of fish purchasing data. It is noteworthy that common fish has the highest purchasing share, followed by salmon and sati.

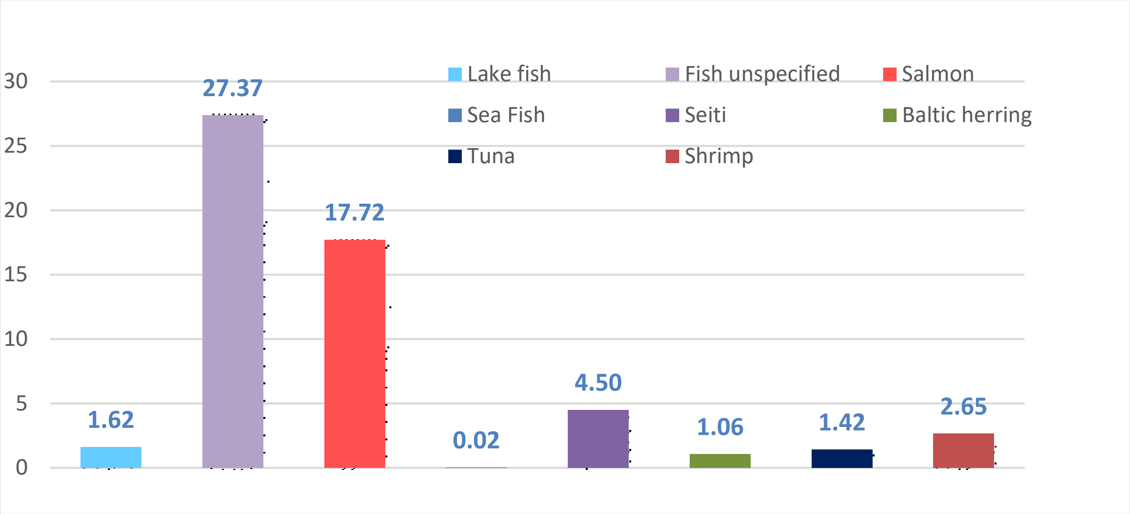

Figure 20. Emission shares of fish categories (CO_2eq).

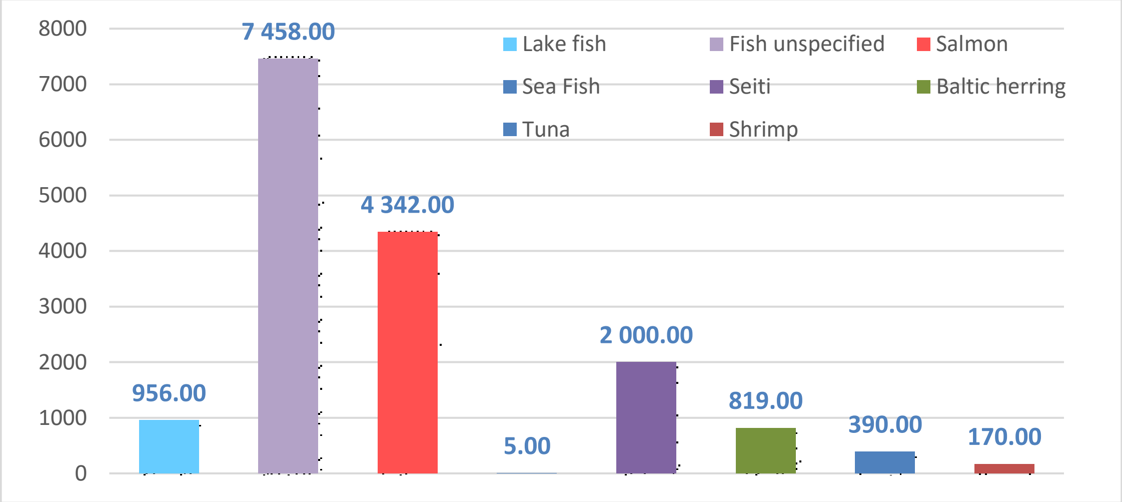

Figure 21. Purchasing shares of fish categories (kg).

6.1.6 Cereal and side dishes

Cereals and side dishes account for 5.87% of the carbon emissions, emitting 45.4tCO_2eq. Figure 22 depicts the emission percentages of cereal and side dishes, while figure 23 illustrates the percentage purchasing of cereal and side dishes. A significant portion of the CF and purchasing can be attributed to potato products, which account for nearly half of the cereal and side dish type purchases. Although rice consumption is less significant in terms of quantity, it contributes to 15% of the emissions.

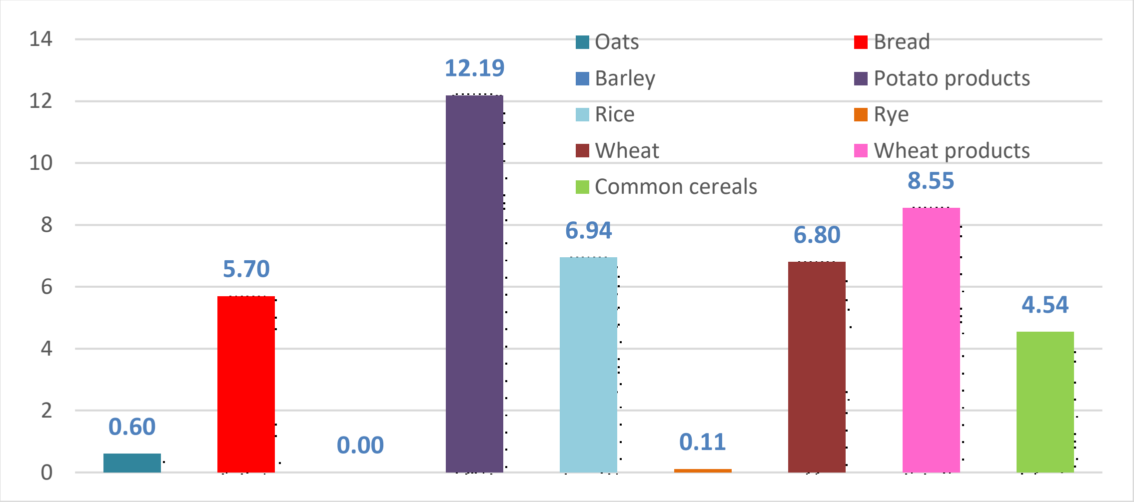

Figure 22. Emissions shares of Cereals (tCO_2eq).

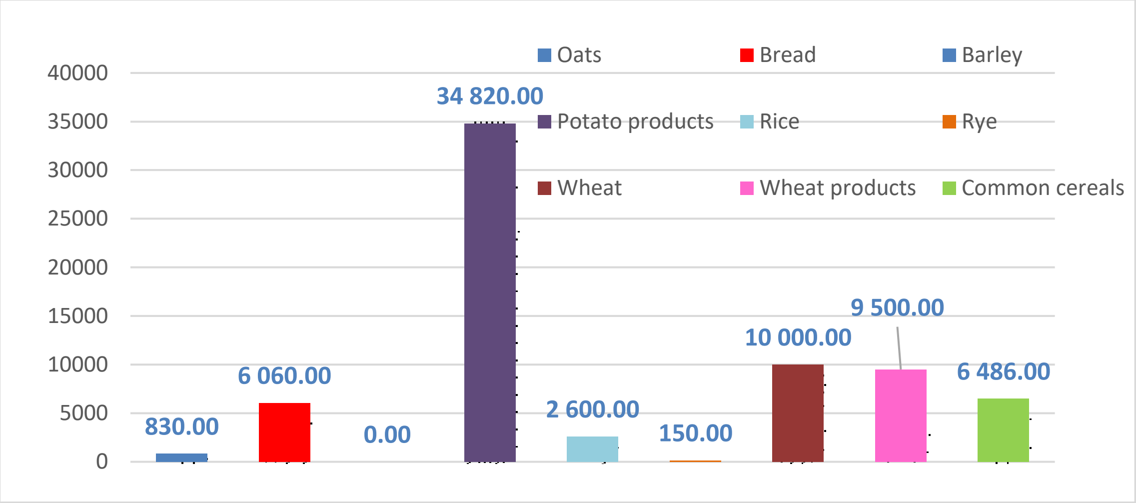

Figure 23. Purchasing shares of cereals and side dishes (kg).

6.1.7 Beverages

Beverages account for 2.74% of CF, emitting $21.20tCO_2eq$. Furthermore, it represented 2.6% of total food purchases amounting to 8742kg. The emission share of beverages is shown in figure 24, while figure 25 illustrates the purchasing share of emissions.

Nearly three-quarters of emissions from beverages are attributed to coffee despite accounting for only 30% of the purchases. On the other hand, soft beverages, the largest share of drink purchases at 33% of purchases, are responsible for only 4% of emissions.

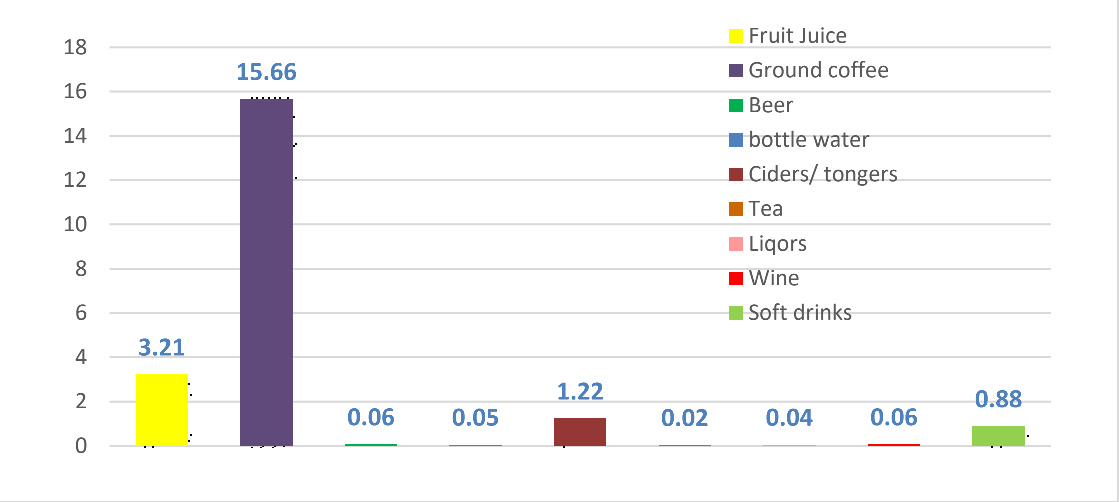

Figure 24. Emission share of beverages (tCO_2eq).

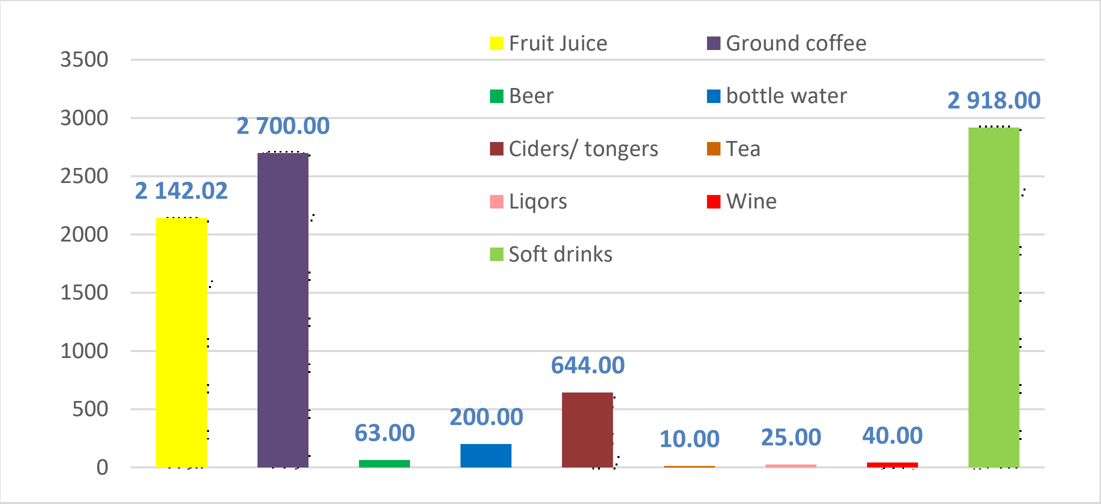

Figure 25. Purchasing share of beverages (kg).

6.1.8 Fruits and berries

Fruits and berries accounted for 1.5% of carbon emissions emitting $11.6tCO_2eq$. Figure 26 illustrates the emission fractions responsible for each food category while figure 27 shows the purchasing shares. A total of 11,763 kg of fruits and berries were purchased, representing 3.5% of the total purchases.

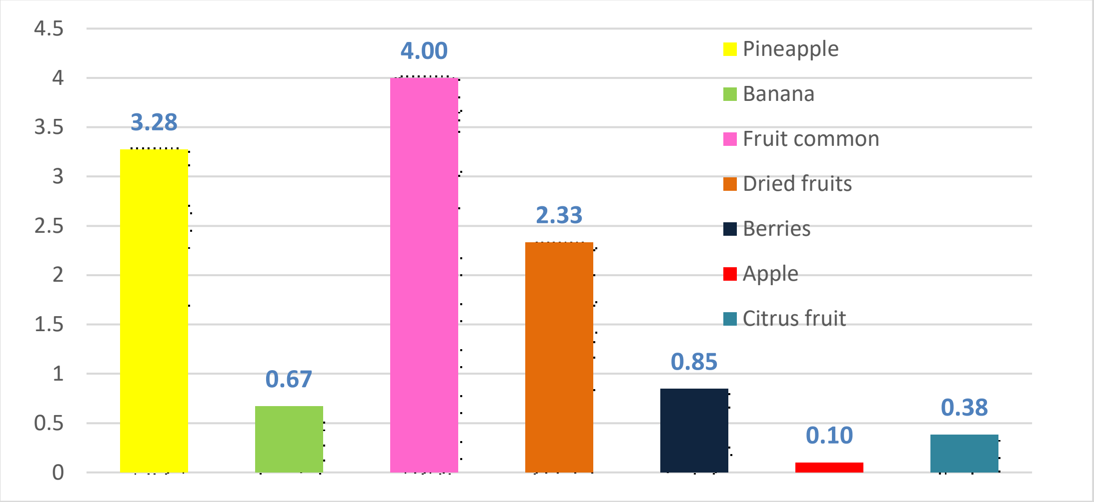

Figure 26. Share of emissions of fruits and berries (tCO_2eq).

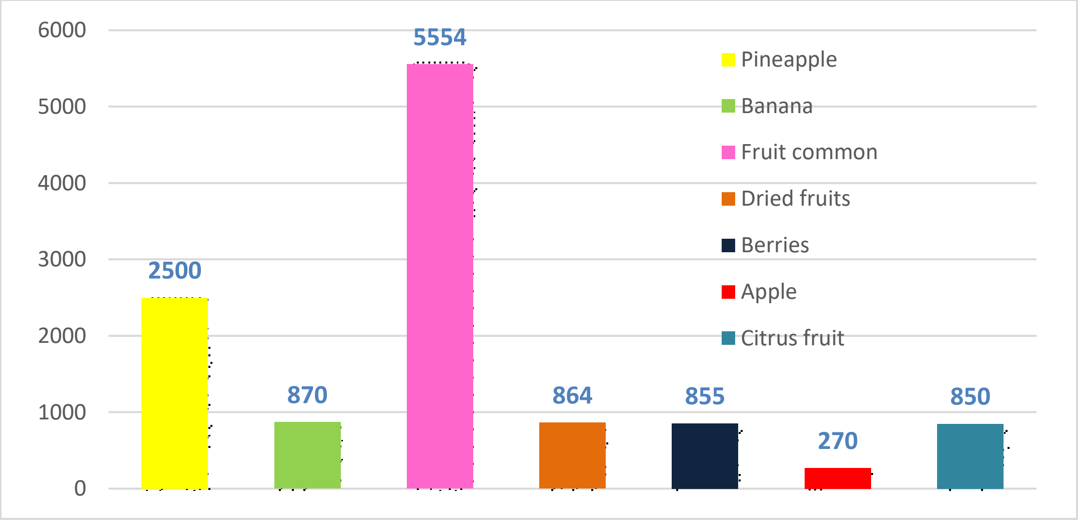

Figure 27. Share of purchasing of fruits and berries (kg).

6.1.9 Plant-based proteins

Plant-based proteins had relatively lower purchases in restaurants. Figure 28 depicts the related purchasing shares with a total of 9253kg of plant proteins being purchased, accounting for 2.75% of total purchases. Peas and dried beans accounted for a quarter of the purchases, followed by lentils and nuts, and seeds. Meat substitutes including vegan meat substitutes, tofu, soy grits, and quorn were less significant. Figure 29 illustrates the contribution of plant-based proteins to emissions which is a less significant amount.

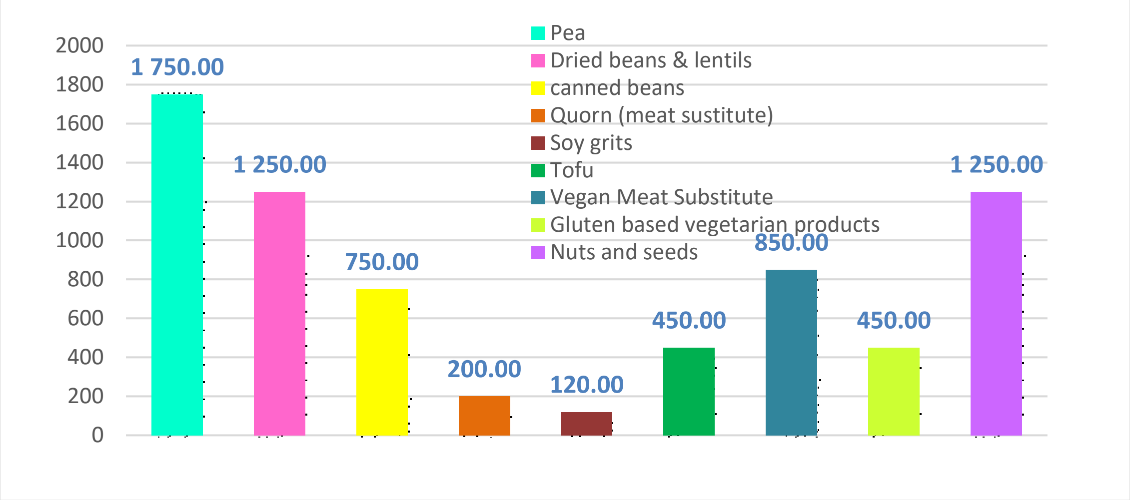

Figure 28. Purchasing shares of plant-based proteins (kg).

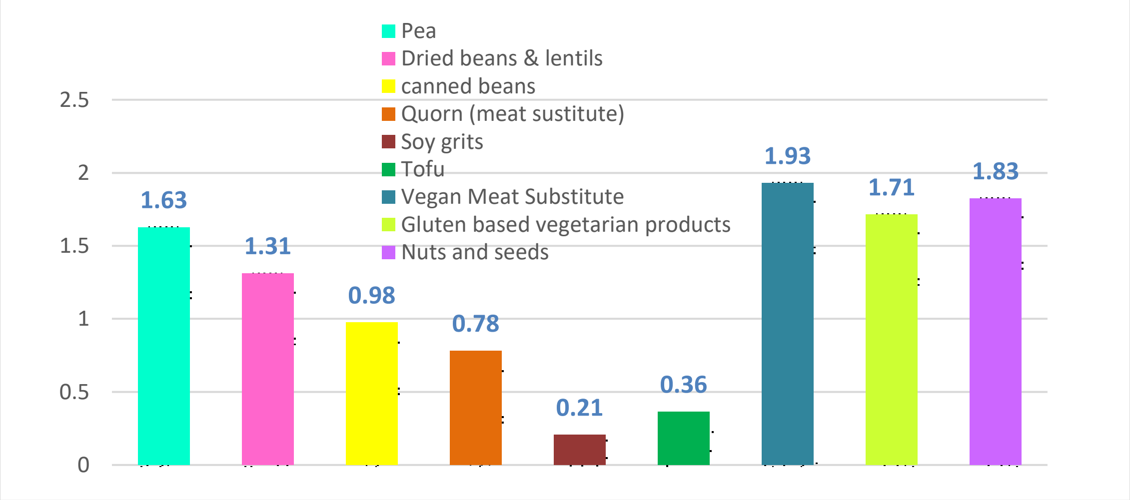

Figure 29. Emission Share of plant-based proteins (tCO_2eq).

6.1.10 Plant-based milk products

The CF of plant-based milk products accounts for 2.74% of the total CF, emitting 21.20 tCO2eq. In terms of purchases, plant-based milk products represent 2.6% of the total weight, with a total of 8,742 kg.

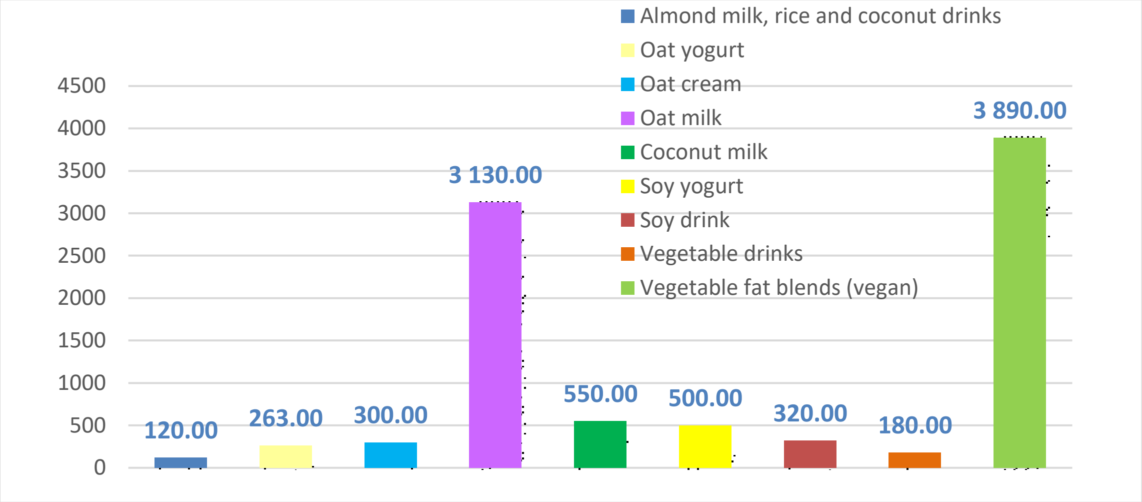

Figure 30. Purchasing share of plant-based milk products (kg).

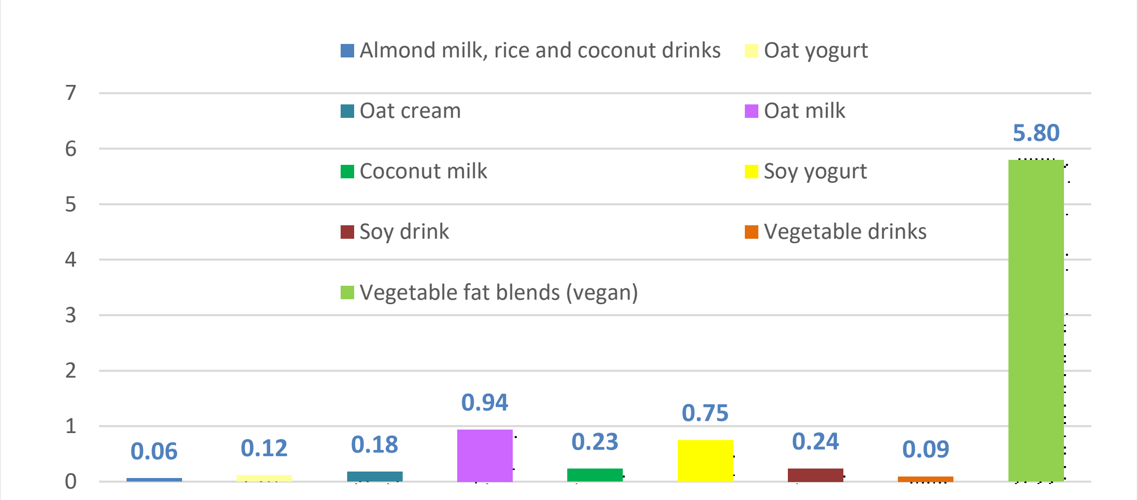

Figure 31. Emission shares of plant-based milk products (tCO_2eq).

6.1.11 Waste

The contribution of waste to the total CF is insignificant which is calculated as 0.577 tCO2eq. In terms of waste generation, a total of 9620.19kg of waste were generated where 82% was generated in the kitchen and only 18% was generated as consumer waste.

7 DISCUSSION AND RECOMMENDATIONS

This thesis was commissioned by the Carbon Footprint Working Group in order to gain a more complete understanding of the environmental impacts of restaurant services at the campus, especially carbon footprint and biodiversity impacts. In addition, the expectation was to make recommendations on how to reduce the carbon footprint of food consumption at the campus restaurants.

7.1 Emission hotspots

According to the results, meat consumption is identified as the largest contributor to the CF followed by dairy milk, and vegetables. Similar results were obtained by Latva-Hakuni (2020) in calculating CF for food services at the University of Jyväskylä, Jungbluth et al. (2016) calculating environmental impacts of canteens of SV group and Helsinki City Environmental Center (2013) CF of Palmia's catering services.

Various food categories exhibit distinct relationships between their emissions and the amounts purchased. Table 2 shows the food items that are responsible for emitting more than 10tCO2 eq and their respective amounts of consumption. These results suggest that the even though the consumption of these food types is low, they still contribute to a significant share of emissions. Examples of such food categories include beef, cheese, ground coffee, ready meat products, salmon, domestic tomato, ready fish products, and pork.

It is notable that although beef is not widely consumed in restaurants, it is the largest contributor to carbon emissions. Processed meat and meat combinations rank second and third respectively in terms of emission contributors. Emissions caused by broilers and their purchasing amounts exhibit a similar pattern, which implies that emissions related to broilers are greater due to their consumption. Furthermore, broiler dishes are considered meat associated with low CF relatively when it is compared to beef (Brunner et al. 2018). Pork consumption is less significant, but its emissions are relatively significant.

Table 2. Food varieties emit more than 10tCO2eq and their respective purchases.

Food variety	Emissions (tCO2eq)	Amount of purchased/t
Beef	113.23	3.93
Meat combination	86.73	6.40
Processed meat	60.87	9.66
Milk	40.39	42.51
Broiler	37.32	7.35
Cheese	33.97	4.05
Vegetables unspecified	31.42	30.22
Fish unspecified	27.37	7.46
Dairy products common	27.03	15.44
Meat ready products	24.37	3.11
Diary Cream	22.53	4.56
Domestic Cucumber	21.80	10.90
Salmon	17.71	4.34
Ground coffee	15.66	2.7
Domestic tomato	13.00	5.00
Fish ready meal	12.93	6.47
Potato products	12.19	34.82
Pork	10.79	1.59

There are also food items that contribute to a large share of emissions because they are consumed in large amounts. The examples in these food items are milk, dairy products, and potato products; milk is the fourth highest emission contributor. Additionally, cheese, has a significant contribution to carbon emissions. Furthermore, common dairy products and dairy cream varieties stand out in terms of emissions. Latva-Hakuni (2020) study depicts a similar relationship between cheese consumption and related emission levels.

In terms of vegetable varieties, domestic cucumbers and tomatoes were identified as moderate emission hotspots. The consumption of domestic varieties such as tomatoes and cucumbers tend to be higher compared to their foreign ones. While their CF is slightly higher, it can still be considered a positive factor, that domestic vegetables are chosen over foreign varieties. This is because the water footprint of domestic products is lower (Valkonen 2020)

While fish consumption in university restaurants is relatively low, representing only 4.79 % of total food purchases, fish consumptions are noteworthy in a study conducted by Latva-Hakuni (2020) at food services of the University of Jyväskylä. In Oulu, salmon contributes significantly to overall emissions. As depicted by section 6.1.6, rice also has a relatively significant emission level. Furthermore, potato and potato products are responsible for considerable emission levels due to their higher consumption level.

7.2 Biodiversity hotspots

The food items that are extensively purchased at university restaurants align with the ten food items identified by Kortesoja et al. (2022) with a notable impact on biodiversity. These include milk, milk products (cheese, common dairy products, and dairy cream), wheat, wheat products, and broiler.

In addition, meat varieties including beef and pork also pose significant threats to biodiversity, although the consumption levels are lower. Processed meat, meat combinations, and meat-ready products originating from these meat varieties are also contributing to biodiversity threats. Additionally, from imported food items, coffee and rice can be mentioned, since both food types have noteworthy impacts on biodiversity in the countries where they are cultivated.

7.3 Recommendations to reduce the carbon footprint of food services.

it is expected that increasing awareness about the health and environmental benefits of vegetarian food may contribute to promoting its consumption to some extent (Spencer and Guinard (2018)). Visual aids such as posters could be displayed in prominent areas, providing information on the positive impacts of sustainable dietary habits. In addition, conducting awareness programs through social media platforms could be used to spread information and create a platform to engage in discussions. Nonetheless, awareness is not enough to motivate customers to choose low-CF food. This would require a systematic methodology to be developed and adapted in the restaurants.

Research by Bianchi et al. (2018) suggests that the physical microenvironment, including reducing the size of meat portions, providing meat alternatives, and manipulating the sensory properties of meals can influence the decision to reduce meat consumption. Directly substituting meat or milk with substitutes may not always satisfy customer preferences and can present various challenges. Therefore, it is important to choose alternative options wisely, taking customer satisfaction into account (Spencer and Guinard 2018).

Sensory pleasure plays a significant role in influencing food choices, so it is essential to prepare vegan or vegetarian dishes with delicious flavors to promote and encourage consumer selection (Spencer and Guinard 2018). Additionally, modifying existing recipes to increase the plant-based portion and creating new sustainable meals is a crucial step toward compensating for carbon emissions (Speck et al. 2020).

Different plant proteins can be used for low CF dishes instead of meat. In Finnish cuisine, commonly used plant proteins include peas, broad beans, and oats. Broad beans are specifically cultivated as germinated products with a focus on plant protein content (EXPRO 2022). Increasing attention is being given to the expansion of broad bean cultivation (Jayakodi et al. 2023) due to the market demand for plant-based proteins. In 2022, the production of broad beans reached 19 million kg in Finland (OSF: Natural Resources Institute Finland 2023a). Additionally, lentil production has gained significant attention in the past decade (Lizarazo and Stoddard 2012). Oats are produced and imported to Finland for use as a gluten-free plant-based food and beverage ingredient.

The Finnish food industry demonstrates great potential for innovative plant-based protein sources. One such example is rapeseed, which is used as rapeseed powder, providing an innovative plant-based protein option (EXPRO 2022).

The utilization of soy products as substitutes for meat and milk raises several concerns regarding biodiversity. Soy cultivation in tropical countries has significant environmental impacts that need to be taken into account. When purchasing soy products as meat substitutes, it is crucial to consider the sustainability concerns of retailers. European soy production, on the other hand, has relatively lower impacts on biodiversity (Foley et al. 2011).

When considering substituting, it is important to note that meat or dairy products cannot be replaced by alternatives in the exact same proportions, and changing recipes also affects the quantities of raw materials required (Latva-Hakuni 2020). Notwithstanding, substitution has the potential to reduce the CF of meals.

Considering the results, fish consumption is currently relatively low in university restaurants. Therefore, substituting meat with sustainably sourced fish can be an effective approach. In addition, replacing Norwegian salmon with sustainably cultivated rainbow trout and Baltic herring can make a significant impact as well (Kaljonen et al. 2020). Furthermore, poultry or broiler meal consumption can be used as an alternative to beef dishes, since their emissions are lower than that of beef. (Brunner et al. 2018)

Nudging is recognized as an effective method to increase the share of vegetarian food in restaurants. Kurz (2018) demonstrated that increasing the visibility of vegetarian food and changing the menu order by listing vegetarian options at the top improves the sales fraction of these dishes. Moreover, nudging allows restaurant chefs to experiment with and test new menus and recipes with lower CF (Kaljonen et al. 2020). Implementing “vegetarian days” at least once per week in restaurants could also help promoting vegetarian food (Lombardini and Lankoski 2013). Overall, setting appropriate vegetarian meal choices is far better than restrictions (Kurz 2018).

Studies have shown that labels presenting the emission factors of meals can influence food choices. For instance, a study by Brunner et al. (2018) highlighted that climate color labels had a moderate impact on food choices. Green labels indicating low CF significantly improve the sales of those meat options (e.g., poultry) compared to red labels for high-CF options (e.g., red meat).

Purchasing food from retailers that have low CF is another strategy for emission reduction. This is notable when purchasing vegetables rather than seeking alternatives. However, only a few food companies publicly disclose their CF or climate impact information (Jungbluth et al. 2016).

Moreover, price control can be a factor to influence meal choices, particularly in student restaurants (Lorenz and Langen 2018). Offering discounts, rewards or reduced prices of vegetarian dishes can have a significant impact on student meal choices. For instance, the Unicafe restaurant chain in Finland reduces the price of vegetarian meals (Unicafe 2020). A small reduction of a few cents will influence customer choices greatly (Garnett et al. 2015). Furthermore, implementing a rewards program specifically for purchasing vegetarian or vegan meals is another effective option for influence. For example, programs providing rewards for buying vegetarian meals within a designated time period could be suggested. (Unicafe 2022).

Reducing food waste is crucial for both biodiversity conservation and CF reduction. However, the lack of available data on food waste at university restaurants makes it difficult to address this issue. The initial step in addressing the food waste issue should be to accurately measure the quantities of food that are being wasted. (Silvennoinen et al. 2019). It is crucial to maintain waste records not only for customer leftovers and kitchen waste but also for separate categories such as surplus food and discarded brewed coffee. By keeping track of these specific sources of waste, university restaurants can gain a better understanding of their food waste patterns and implement targeted strategies to minimize waste and its associated environmental impacts.

One approach to tackle customer waste is by increasing awareness about the impacts of food waste. When individuals see the actual quantities and the associated costs of their plate leftovers, they are more likely to consider reducing food waste. On the other hand, informational interventions are identified as relatively ineffective methods for substantial behavioral changes although it is the prevailing predominant method. To complement these efforts, non-informational interventions including modeling social norms, using prompts, and providing have shown promising results. (Stöckli et al. 2018) Rewards may include giving rewards for donating overstocked products to non-profit associations that are necessary for human consumption can be donated for aid (Finnish Food Authority 2021)

To effectively address the issue of surplus food at restaurants, one approach is to sell it at discounted prices, (Silvennoinen et al. 2019). To facilitate this, various digital platforms can be utilized. For example, the restaurant Kampusravintolat Oy at LAB University of Applied Sciences in Lappeenranta, Finland, sells its surplus food through the ResQ club platform (Ngoc Linh 2020). This approach allows restaurants to reduce food waste and offer affordable options to customers while benefiting from the efficient redistribution of excess food.

7.4 Emission reduction scenarios

In order to reduce emissions, reducing the consumption of food associated with high CF and using alternatives is the direct solution. Meat and milk are identified as some of the highest contributors to emissions and biodiversity threats in university restaurants. Thus, decreasing their consumption should be aimed at. This section focuses on substituting meat and milk products with substitutes associated with lower CF.

Table 3. Carbon footprint comparison of meat product substitutes with plant-based proteins.

Meat products	CF (tCO_2 eq)	CF if substitutes are used (tCO_2eq)						
		Quorn	Soy grits	Tofu	Vegan meat substitute	Peas	Dried beans and lentils	Canned beans
Broiler	37.31	28.72	12.63	5.95	16.68	6.83	7.71	9.55
Processed meat	60.86	37.78	16.62	7.83	21.93	8.99	10.14	12.56
Beef	113.23	15.37	6.76	3.18	8.92	3.66	4.13	5.11
Pork	10.79	6.22	2.74	1.29	3.61	1.48	1.67	2.07
Meat Combination	86.73	0.34	11	5.18	14.53	5.95	6.72	8.32

Table 4. Carbon footprint when milk products are substituted.

Milk product	Purchased amount/kg	CF (tCO_2eq)	Substitute	Emission factor (tCO_2eq/kg)	CF (tCO_2eq)
Liquid milk	42517.5	40.39	Almond, rice, or Coconut milk	0.5	21.26
			Oat milk	**0.3**	**12.75**
			Vegetable beverages	0.52	22.11
			Soy drink	29.89	29.89
Yoghurt	2615.19	3.50	**Oat yoghurt**	**0.44**	**1.15**
			Soy yoghurt	1.5	3.9
Cream	4560	40.9	Oat cream	0.6	2.76
			Coconut cream	**0.42**	**1.91**
Milk-based fat mixtures	3495.97	4.57	**Vegetable fat blend (vegan)**	**1.49**	**5.2**

Table 3 provides a comparison of the CF of various meat varieties with several meat substitutes, assuming the same quantities are purchased by the university's restaurant. The calculations indicate that tofu has the lowest emissions among the substitutes, except for meat combinations, where Quorn accounts for the lowest emissions. However, all the meat substitutes significantly reduce emissions.

Similarly, diary milk products can also be substituted with plant-based products. Table 4 shows if milk products including liquid milk, yoghurt cream, and milk-based vegetable blends are substituted by plant-based dairy substitutes.

For the purpose of calculations, three scenarios are considered.

1. 100% meat is replaced with the lowest CF plant-based meat substitutes.
2. 100% of beef, processed meat, and meat combinations are replaced with the lowest CF plant-based meat substitutes.
3. 100% beef, processed meat, and meat combinations and 50% of liquid milk, cream, yoghurt, and milk-based fat mixtures replaced with the lowest CF plant-based substitutes.
4. 50% of beef, processed meat, and meat combinations and 50% of liquid milk dairy cream, yoghurt, and dairy milk-based fat mixtures are replaced with the lowest CF substitutes.
5. 50% milk products and 60% of beef, meat combinations, and processed meat are substituted with 20% tofu 15% lake fish (Järvikala) and 15% Baltic herring (Silakka), and 10% by broiler.

If the lowest CF meat substitutes are used instead of meat varieties, (scenario 1) the CF of food would be reduced by 38% amounting to 476 tCO_2eq. Furthermore, if beef, processed meat, and meat combinations, (scenario 2) which contribute the largest fractions to the CF, are substituted with alternatives with the lowest CF, the total CF of food would be reduced to 525 tCO2eq indicating a 31% drop from the existing CF. If meat (beef, processed meat, and meat combinations) and milk (liquid milk, cream, yoghurt, and milk-based fat mixtures) are 100% replaced with the lowest emitting substitutes (scenario 3), CF is calculated as 361 t CO2eq which is 53% drop from the current amount.

However, substituting all the meat and dairy milk products is not practically possible due to the meal preferences of customers. Therefore, 50% of beef, processed meat, and meat combinations and 50% of liquid milk, cream, yoghurt, and milk-based fat mixtures are substituted with the above-mentioned substitutes (scenario 4), and the CF is calculated as 615 tCO2eq which reduces 20% of carbon emissions.

Although cheese is identified as an emission hotspot, currently restaurants are not utilizing any cheese substitutes. Therefore, it is not included in the emission reduction scenarios. Nevertheless, it is crucial to explore alternatives suitable for cheese in meal preparation in order to reduce CF.

In addition to that, it is possible to replace meat consumption with sustainably sourced low-CF broiler, and plant-based dishes (Scenario 5). So, 50% of milk products are substituted by the lowest emitting plant-based milk products, and 60% of beef, meat combinations, and processed meat consumptions are substituted with 20% tofu 15% lake fish (Järvikala) 15% baltic herring (Silakka), and 10% by broiler, a 22% reduction in carbon emissions can be achieved.

Table 5 shows the summary of the discussed scenarios. It is important to note that substituting high-CF food varieties is a crucial step toward achieving carbon neutrality and sustainability in food services.

Table 5. Summary of emission reduction scenarios.

Scenario	CF (tCO_2eq)	Percentage CF reduction/%
1. 100% meat is replaced with the lowest CF meat substitutes.	476	38
2. 100% of beef, processed meat, and meat combinations are replaced with the lowest CF substitutes.	525	31
3. 100% beef, processed meat, and meat combinations and 50% of liquid milk, cream, yoghurt, and milk-based fat mixtures replaced with the lowest CF substitutes.	361	53
4. 50% of beef, processed meat, and meat combinations and 50% of liquid milk diary cream, yoghurt, and diary milk-based fat mixtures are substituted with the lowest CF substitutes.	615	20
5. 50% milk products and 60% of beef, meat combinations, and processed meat are substituted with 20% tofu 15% lake fish (Järvikala) and 15% Baltic herring (Silakka), and 10% broiler.	600	22

7.5 Limitations

The calculation of CF is based on the purchasing details recorded by the restaurant providers. It is important to note that the two different restaurant providers have employed different methods for maintaining their purchasing details. As a result, there may be a lack of uniformity in the recorded information. For example, some food purchases are recorded as a food group (e.g.: vegetables, fish, frozen food, and fruits), which makes it impossible to calculate the exact CF.

Additionally, there were some limitations regarding the categorization of the purchase data. The data provided by Juvenues was in a format where the purchasing amounts were already categorized into 97 different categories (as mentioned in chapter 5.3). However, for Uniresta, the data was received in the form of purchasing documents, and the categorization was done manually. This introduces a level of uncertainty in the grouping process. On the other hand, it is crucial to group some of the food items for instance seasoning, preservatives, and sweeteners, into one of the categories among the 97 categories. Furthermore, certain data, such as waste amounts, were missing from the records of the restaurant service providers.

To address potential inaccuracies in the calculations, it is crucial to request that restaurant service providers about the importance of maintaining clear and comprehensive data. This includes emphasizing the need to group food varieties and track waste amounts diligently methodically. By doing so, the accuracy of calculations can be improved significantly. Enhancing the communication between the university and the restaurant service providers is essential for developing appropriate strategies and implementing effective solutions. Improving communication will allow better collaboration and facilitates the timely addressing the challenge of reducing CF.

When collecting data, it is beneficial to obtain detailed purchasing records directly from the restaurant providers. This helps in ensuring precise categorization of food varieties and accurate calculations. Having access to this information allows for a more thorough analysis and it aids in identifying areas where improvements can be made.

Additionally, it is essential to keep records of the number of plates sold. This data is valuable in calculating the CF and customer-generated waste per plate. By quantifying waste on a per-plate basis, it becomes easier to track and monitor waste reduction progress. Furthermore, expressing waste data in this manner serves as a clear representation of the environmental impact and can be an effective method for raising awareness among restaurant staff and customers.

In order to effectively implement waste reduction strategies, it is highly recommended to maintain accurate records of waste data in various waste categories, such as customer waste, kitchen waste, waste due to unsold food, and brewed coffee waste. This systematic approach enables a better understanding of where waste is generated and how it can be minimized.

8 CONCLUSIONS

Reducing greenhouse gas emissions and preserving biodiversity are of paramount importance. Finland's carbon neutrality goal has prompted educational institutes to plan and implement sustainability-focused actions. The objectives of this thesis were to assess the biodiversity impacts and calculate the CF of food services at the University of Oulu, and provide suggestions on how to reduce the CF of restaurant services.

The food system is responsible for a considerable amount of global greenhouse gas emissions, primarily from food production, consumption, and wastage. Agriculture, food processing, storage, transportation, and packaging also contribute significantly. Furthermore, the food system has significant negative impacts on biodiversity. Land use change, including deforestation and altering natural habitats, leads to habitat loss and fragmentation, causing biodiversity loss. Soil erosion, the introduction of non-native species, and the use of agrochemicals also pose threats. Eutrophication and water scarcity are consequences of the food system, affecting aquatic ecosystems. Food waste and loss contribute to wasting natural resource and environmental degradation. Each stage of the food chain contributes to greenhouse gas emissions significantly.

Carbon footprint is an effective tool to assess greenhouse gas emissions as carbon dioxide equivalents (CO2eq), and it is widely used by many institutes to assess impacts and achieve carbon neutrality goals. The CF of food services at the University of Oulu for 2022 was calculated to be 770 tCO2eq, which is higher in value compared to the year 2021. The most significant contributors are meat varieties and milk products. Further, coffee, salmon, domestic cucumber and tomato, fish ready-meals, and potato products can be identified as other high-CF food varieties. Regarding biodiversity, milk products, beef, wheat and wheat products, broiler, coffee, and rice can be identified as hotspots.

To effectively reduce CF and mitigate the environmental impact of food services, it is crucial to systematically address practical solutions. In this study, five such scenarios were considered. The CF of food services would be halved, if we substituted all meat and milk products with plant-based products. Substituting 50% of meat and milk with plant-based products can result in a 20% reduction in CF. Alternatively, incorporating fish, plant-based protein, and broiler meat for 60% of meat consumption and using plant-based products for 50% of milk consumption can lead to a 22% reduction in CF. These scenarios highlight the significant potential for CF reduction by utilizing alternatives to high-CF meat and milk varieties served at university restaurants. It is important to explore and promote these low-CF alternatives systematically.

The identification of CF and biodiversity hotspots of the restaurant services enables the university to prioritize its carbon neutrality efforts effectively. The practical measures proposed in the study serve as a roadmap to implementing sustainable practices within restaurants. Furthermore, restaurant providers benefit from this study, as it offers valuable guidance to reducing the CF and achieve sustainable food service operations.

One crucial aspect is to influence customers to choose low-CF food options. This requires the implementation of a supportive systematic tool that encourages sustainable choices. Strategies for reducing meat and milk consumption can include substituting them with plant-based products without compromising customer satisfaction in terms of sensory pleasure. Existing recipes can be modified to incorporate delicious substitutes and new recipes can be introduced to diversify options. Additionally, incorporating fish and broilers as alternatives to high-CF meat varieties can help reduce impact. Restaurants can offer a wider range of vegetarian and vegan options, providing more choices for customers seeking plant-based meals. To incentivize sustainable choices, prices for vegan or vegetarian meals can be reduced, and rewards can be offered for selecting these options. Purchasing from retailers with stronger sustainability concerns is another important step. By prioritizing suppliers with a focus on sustainability, restaurants can support more environmentally friendly practices. Accurately measuring food waste is essential in addressing the CF issue effectively. Creating customer awareness is crucial, and one way to combat food waste is to sell surplus food at affordable prices.

Effective communication among the university, restaurant providers, and customers (students and staff) is essential in this pathway. Informing and explaining research findings to restaurant providers is vital since their feedback is invaluable in CF reduction actions. In addition, customer feedback is important in terms of innovative meal recipes, and meal plan changes. Customer satisfaction is always a priority of restaurants, even while achieving climate neutrality and sustainability goals.

This study provides a framework for other institutes that are interested in climate change mitigation, to undertake similar research. The lessons learned and best practices identified regarding the assessment of CF and implementing reduction measures during the study can guide other institutes in their journey toward sustainability. The study provides insights into effective strategies, potential challenges, and innovative approaches for CF reduction associated with restaurants. Further, this study allows for collaboration and knowledge sharing among universities and institutes that are developing a platform to address common sustainability challenges. Ultimately, this information and experience sharing leads to accelerating progress toward climate neutrality and sustainability across universities.

From the perspective of society, this study highlights concerns of dietary habits and food services which is a critical sustainability challenge within the society. The recommendations and findings increase awareness regarding the environmental consequences of food choices and promote sustainable dietary practices. The outcomes of this study have the potential to contribute to broader discussions in climate change mitigation and sustainable food systems which benefit society, inspire individuals' behavioural changes, and promote the culture of sustainability.

It is highly recommended to overcome the limitations identified in this study for future calculations of CF and other research in this regard. One crucial issue is improving the data recording and clarity of purchasing details and waste generation. These data sets are essential for the accuracy of assessing the CF. Provided with more comprehensive data, future CF calculations can provide more precise and reliable outcomes, which will ultimately impact the climate neutrality roadmap.

Furthermore, it is recommended that the biodiversity impacts of food services at university restaurants should be researched separately, to obtain more specific details. This study provides only a general overview and highlights some key biodiversity hotspots. More information on biodiversity impacts would enable a more comprehensive understanding of environmental footprint and support targeted measures to mitigate biodiversity loss.

This study supported the Carbon Footprint Working Group in its ongoing efforts supporting the carbon neutrality objective of the University of Oulu. The proposed methods and strategies outlined in this study are expected to be practiced at university restaurants in order to achieve both the university’s and restaurant service providers' climate and sustainability goals. The results will be incorporated in the 2022 CF of University of Oulu. Ultimately, the thesis will assist the University of Oulu on its path to climate neutrality.

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THESIS APPENDICES

Appendix 1 (Latva-Hakuni 2020)

	Food Category	Emission factor/tCO2eq	Purchased amounts/kg	Emissions/ tCO2eq
	Vegetables		78036	88.16
1	Root Vegetables (carrot, beet, turnip, radish, etc)	0.37	14500	5.37
2	Cabbage (cabbage, cauliflower, broccoli, kale, brussels sprouts)	0.60	2090	1.25
3	Domestic Cucumber	2.00	10900	21.80
4	Foreign Cucumber	0.33	550	0.18
5	Leafy vegetables (Salads, spinach, fresh herbs)	1.00	9500	9.50
6	Maize	1.17	400	0.47
7	Mushrooms	2.14	430	0.92
8	Onions (yellow and red onions, garlic, and leek)	0.34	950	0.32
9	Domestic tomato	2.60	5000	13.00
10	Foreign Tomato	1.12	3500	3.92
11	Vegetables common	1.04	30216	31.42
	Fruits and berries		11763	11.61
12	Pineapple	1.31	2500	3.28
13	Banana	0.77	870	0.67
14	Fruits unspecified	0.72	5554	4.00
15	Dried fruits	2.70	864	2.33
16	Berries	0.99	855	0.85
17	Apple	0.37	270	0.10
18	Citrus fruit (orange, tangerine, lemon)	0.45	850	0.38

	Cereals and side dishes		70446	45.42
19	Oats	0.72	830	0.60
20	Bread	0.94	6060	5.70
21	Barley	0.85	0	0.00
22	Potato products	0.35	34820	12.19
23	Rice	2.67	2600	6.94
24	Rye	0.71	150	0.11
25	Wheat	0.68	10000	6.80
26	Wheat products (Pasta, tortilla, etc)	0.90	9500	8.55
27	Cereal mixtures (flour mixtures, buckwheat, malted barley, and others)	0.70	6486	4.54
	Plant Proteins		7070	10.74
28	Pea	0.93	1750	1.63
29	Dried beans & lentils	1.05	1250	1.31
30	Canned beans	1.30	750	0.98
31	Quorn (meat sustitute)	3.91	200	0.78
32	Soy grits	1.72	120	0.21
33	Tofu	0.81	450	0.36
34	Vegan Meat Substitute	2.27	850	1.93
35	Gluten-based vegetarian products	3.81	450	1.71
36	Nuts and seeds	1.46	1250	1.83
	Meat and Egg		30673.111	312.71
37	Broiler	5.08	7346.044	37.32
39	Egg	2.22	1620	3.60
40	Lamb	29.63	4	0.12
41	Processed meat	6.30	9661.432	60.87
42	Beef	28.80	3931.45	113.23
43	Game meat	0.50	118.53	0.06

44	Pork	6.78	1592.098	10.79
45	Meat combination	13.55	6399.557	86.74
	Fish		16140	56.35
46	Lake fish (Ex: Zander, white fish, pike)	1.69	956	1.62
47	Fish unspecified (mixed fish products and unspecified fish varieties)	3.67	7458	27.37
48	Salmon	4.08	4342	17.72
49	Sea Fish	4.20	5	0.02
50	Seiti	2.25	2000	4.50
51	Baltic herring	1.29	819	1.06
52	Tuna	3.63	390	1.42
53	Shrimp	15.59	170	2.65
	Milk products		73461.51	139.81
54	Yoghrt	1.34	2615.19	3.50
55	Cheese	8.39	4049	33.97
56	Diary cream	4.94	4560	22.53
57	Milk	0.95	42517.5	40.39
58	Diary products common (curds, ice creams, pudding, etc)	1.75	15443.85	27.03
59	Butter	10.01	780	7.81
60	Vegetable fat mixtures (milk-based fat mixtures ex: rapeseed oil and additives)	1.31	3495.97	4.58
	Plant-based milk products		9253	8.40
61	Almond milk, rice, and coconut drinks	0.50	120	0.06
62	Oat yogurt	0.44	263	0.12
63	Oat cream	0.60	300	0.18

64	Oat milk	0.30	3130	0.94
65	Coconut milk	0.42	550	0.23
66	Soy yogurt	1.50	500	0.75
67	Soy drink	0.74	320	0.24
68	Vegetable drinks	0.52	180	0.09
69	Vegetable fat blends (vegan)	1.49	3890	5.80
	Oils		2800	7.65
70	vegetable oils in general	2.03	600	1.22
71	olive oil	4.33	300	1.30
72	Rapeseed oil	2.70	1900	5.13
	Spices		3407	2.68
73	Honey	1.10	70	0.08
74	General spices (dried)	1.37	300	0.41
75	Sugar	0.76	2837	2.16
76	Salt	0.20	200	0.04
	Sweets		2906	5.19
77	Pastries (cookies, cake pastry, etc)	1.78	2322	4.13
78	chocolate	1.95	400	0.78
79	sweets (cadies)	1.53	184	0.28
	Finished products		21970.3	59.68
80	Fruit products (Jams, purees,..)	2.25	1900	4.28
81	Fish ready meal	2.55	6472	12.93
82	Vegetable ready products	1.70	3471	9.48
83	Meat ready products	7.83	3112	24.37
84	Mayonnaise	1.95	650	1.27
85	Seasoning Sauce	2.25	568.5	1.28
86	Tomato products	1.27	1801	2.29
87	Canned vegetable and fruit	0.90	3845.8	3.46

88	Wine vinegar	2.24	150	0.34
	Drinks		8742.02	21.20
89	Fruit Juice	1.50	2142.02	3.21
90	Ground coffee	5.80	2700	15.66
91	Beer	0.97	63	0.06
92	bottle water	0.23	200	0.05
93	Ciders/ tongers	1.90	644	1.22
94	Tea	2.45	10	0.02
95	Liqors	1.70	25	0.04
96	Wine	1.47	40	0.06
97	Soft drinks	0.37	2918	0.88
	Waste		9620.19	0.58