Reduction of carbon footprint of meals in Sisak elementary schools

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REDUCTION OF CARBON FOOTPRINT OF MEALS IN SISAK ELEMENTARY SCHOOLS

This study was carried out in the Laboratory for Measurement, Control and Automatisation at the Department of Process Engineering of Faculty of Food Technology and Biotechnology at the University of Zagreb under supervision of PhD Jasenka Gajdoš Kljusurić, full profesor with the assistance of Diana Gluhak Spajić, MSc Nutrition.

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REDUCTION OF CARBON FOOTPRINT OF MEALS IN SISAK ELEMENTARY SCHOOLS

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Abstract: Meal preparation is associated with a high carbon footprint, which results from many factors directly or indirectly related to the food production, transportation and energy consumption during meal preparation. This study aimed to analyze and optimize the efficiency of school kitchens in Sisak. The project was implemented in 9 elementary schools from 2020 to 2022. The results of the study confirmed the previous knowledge that foods of animal origin increase the carbon footprint of meals. Optimized meals have a low carbon footprint (< 376 g CO_2 eq) and simultaneously provide all macronutrients and energy needs per national guidelines. The results of measuring the energy consumption of kitchen devices showed that the cooling devices in schools are inefficient, unmaintained and incorrectly installed. Each school received recommendations to improve the efficiency of kitchens in order to reduce greenhouse gas emissions and protect the climate.

Keywords: *CO_2 footprint, school meals, reduction, climate friendly meals*
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SMANJENJE UGLJIČNOG OTISKA OBROKA U SISAČKIM OSNOVNIM ŠKOLAMA

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Sažetak: Priprema obroka povezana je s visokim ugljičnim otiskom, koji proizlazi iz mnogih čimbenika izravno ili neizravno povezanih s proizvodnjom prehrambenih proizvoda, njihovim transportom i potrošnjom energije tijekom pripreme obroka. Cilj ovog rada bio je analizirati i optimizirati učinkovitost školskih kuhinja grada Siska. Projekt se proveo u 9 osnovnih škola od 2020. do 2022. godine. Rezultati studije potvrdili su dosadašnje spoznaje da namirnice životinjskog porijekla povećavaju ugljični otisak obroka. Optimizirani obroci imaju nizak ugljični otisak (< 376 g CO_2 eq) i ujedno osiguravaju sve makronutrijente i energiju u skladu s nacionalnim smjernicama. Rezultati mjerenja električne energije kuhinjskih uređaja u razdoblju od dva tjedna su pokazali da su rashladni uređaji u školama neučinkoviti, neodržavani i krivo postavljeni. Svaka škola dobila je preporuke za poboljšanje učinkovitosti rada u kuhinji kako bi se smanjila emisija stakleničkih plinova u cilju zaštite klime.

Ključne riječi: *CO_2 otisak, školski obroci, smanjenje, klimatski prihvatljivi obroci*
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1. INTRODUCTION

The food sector causes climate change but is also affected by climate change. It is responsible for a third of greenhouse gas emissions which cause heat retention in the atmosphere and global warming. With an increase of 2 billion people predicted by 2050, which requires greater food needs, efforts must be focused on increasing sustainability and reducing greenhouse gas emissions from food systems while ensuring sufficient amounts of food (Volanti et al., 2021). For this reason, the EU decided to adopt measures and policies to reduce greenhouse gases to be climate neutral by 2050 (EUR-Lex, 2019). Sustainable nutrition presents the main lever for reducing climate change. It has several aspects and is defined as nutrition that ensures the health and well-being of the individual; it is affordable, safe and available, and it has low pressure and impact on the environment (Polleau and Biermann, 2021). Governments play the role of the main drivers of change, and one way of acting is to improve the sustainability of public nutrition, such as school nutrition (De Laurentiis et al., 2017). Schools are educational institutions that, by promoting proper nutrition, positively affect students' health. Children form their eating habits at school, and school meals are ideal for promoting more sustainable habits. Learning about sustainable nutrition can influence their future behaviour, which ultimately impacts the sustainability of the food system (Nogueira et al., 2021).

The aim of this study was to assess the environmental impact of elementary school kitchens in Croatia through two steps: 1) by optimizing ten school meals into nutritionally rich meals with a low carbon footprint for children aged 7-9 years, and 2) by measuring the electrical consumption of cooling kitchen appliances.

2. LITERATURE REVIEW

2.1. EUROPEAN UNION (EU) ENVIRONMENTAL POLICY REGARDING FOOD PRODUCTION

The United Nations (UN) defined climate change as long-term changes in temperature and weather patterns resulting from natural phenomena and human activities. Human activities, more precisely, unsustainable energy use, land use, lifestyle, excessive consumption and production that have been creating greenhouse gases (GHG) for more than a century, are the primary driver of climate change (UN, 2022). Greenhouse gases have a "greenhouse effect", i.e. they retain heat in the atmosphere, which leads to the warming of the Earth. They include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases (EPA, 2022). According to the sixth report of the Intergovernmental Panel on Climate Change (IPCC) from 2021, warming of 1.5 °C - 2 °C is predicted in the coming decades if there is no reduction in GHG emissions. The previously described global warming represents a risk to humans and other life forms on Earth. Higher temperatures result in a change in weather patterns that bring more intense rainfall and flooding, droughts in certain regions, melting of permafrost, melting of glaciers and ice sheets, loss of summer Arctic sea ice, changes in the ocean (more frequent marine heat waves, ocean acidification and reduced oxygen levels) and heat in urban areas and sea level rise in coastal cities. The changes mentioned above significantly affect the quality of life and health of people, animals and plants, which prompted the EU to adopt a series of measures and policies to reduce greenhouse gases and achieve a climate-neutral society (IPCC, 2021).

The Kyoto Protocol, adopted on December 11, 1997, at the Third Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC), is the first binding agreement to reduce greenhouse gases. The Kyoto Protocol entered into force on February 16, 2005, and consists of two commitment periods. In the first commitment period, from 2008 to 2012, the industrialized member countries set the main goal of reducing greenhouse gas emissions by an average of 5 % compared to 1990 levels, and they were enabled to achieve a joint reduction of greenhouse gases in the amount of 8 % (EUR-Lex, 2011). After the EU and the EU countries fulfilled the obligations of the first period, in December 2012, at the climate change conference in Doha, they established an amendment to the Kyoto Protocol. In the amendment, it was decided to reduce GHG emissions by at least 18 % in the period from 2013 - 2020 compared to 1990. Iceland, the EU and the EU countries also agreed on a joint reduction of greenhouse gas emissions by 20 % (EUR-Lex, 2016a).

The Paris Agreement was adopted at the conference on climate change in Paris (English Conference of the Parties, COP21), held on December 12, 2015. The Paris Agreement replaces the Kyoto Protocol and is the first legally binding global climate agreement. It entered into force on November 4, 2016, and applies from 2020. By signing the Paris Agreement, 195 countries have pledged to meet the goal of keeping the increase in global average temperature well below 2 °C compared to pre-industrial levels; to make additional efforts to limit the increase to 1.5 °C, which would significantly reduce the risks and consequences of climate change; and committed to submit national action plans to achieve these goals. Within the agreement, the EU and its member states set the primary goal of reducing greenhouse gas emissions by at least 40 % by 2030, primarily by improving energy efficiency and developing renewable energy sources. In order to monitor the progress of the set goals and determine further goals and measures to reduce climate change and global warming, following the Paris Agreement, the parties must conduct a review of the global situation every five years, starting in year 2023 (EUR-Lex, 2016b).

In 2019, the European Commission adopted a Communication called the "European Green Deal". The European Green Deal is a new strategy by which the EU wants to achieve a more sustainable economy and society, preserve people's health and quality of life and care for nature. It consists of several policy areas shown in Figure 1. Within the "European Green Deal", the European Commission presented a proposal to set a new goal related to the net reduction of greenhouse gases by at least 55 % by 2030 (compared to 1990) and to reach net-zero greenhouse gas emissions within the EU and deliver pollution-free environment by 2050 (EUR-Lex, 2019). For these purposes, 35 % of the EU research funding from 2021 to 2027 will be dedicated to developing environment-friendly technologies (EU-ASEAN, 2020).

Figure 1. European Green Deal (EU-ASEAN, 2020)

Data show that ⅓ of total greenhouse gases come from the food system. Crippa et al. (2021) estimated that in 2015, GHG emissions from the food system amounted to 34 %, of which agriculture and land use/changes in land use (71 %) contributed the most. The remaining 29 % came from activity emissions, food processing, transport, packaging, retail, consumption and waste management. For this reason, food systems are at the centre of the "European Green Deal". Moreover, they are included in the "From farm to fork" strategy. The strategy aims to achieve a sustainable food system that will reduce the ecological footprint of the food system, strengthen resistance to crises and provide high-quality, rich in nutrients, safe and affordable food. The "Action Plan for Organic Production" that was adopted within the strategy aims to achieve 25 % of organic agriculture by 2030 (EUR-Lex, 2020).

The "European Green Deal" proposals are also included in the European Climate Law, which entered into force on July 29, 2021. The European Climate Law ensures that the political obligations of the EU in the field of climate become legal obligations. In addition, the Climate Law seeks to enhance the carbon sink and includes a process for setting the European Commission's climate target for 2040; it also states that after 2050 the EU must achieve negative greenhouse gas emissions; and it includes the establishment of European Scientific Advisory Board on Climate Change and sector-specific roadmaps charting the path to climate neutrality (EUR-Lex, 2021b). On April 6, 2022, the European Parliament and the Council established the eighth environmental action program called the Decision on the Union's General Action Program for the environment until 2030. The program builds on the European Green Deal and contains six priority goals: 1. reduction of greenhouse gas emissions by 2030 and the achievement of a climate-neutral Europe by 2050; 2. adaptation to climate change, which implies a change in people's behaviour in order to protect themselves, the environment and the economy; 3. the introduction of a regenerative growth model and the transition to a circular economy ("a circular economy is a system that preserves the value of products, materials and resources in the economy as long as possible and reduces the generation of waste to the minimum possible" (EUR-Lex, 2021a)); 4. zero rates of water, air and soil pollution and protection of the health and well-being of animals, ecosystems and people; 5. protection, preservation and restoration of the biodiversity of the marine and terrestrial world; improvement of the environment (air, water and soil) and improvement of the ecosystem; and 6. reduction of environmental and climate pressure related to production and consumption; and promotion of sustainability (EUR-Lex, 2022).

2.1.1. Climate policy in the territory of the Republic of Croatia regarding food production

The need to prevent and adapt to climate change is also recognized in the Republic of Croatia. On January 17, 1996, the Republic of Croatia became a party to the United Nations Framework Convention on Climate Change, which was confirmed by adopting the Law on its ratification (Zakon, 1996). Accordingly, the Republic of Croatia signed the Kyoto Protocol on March 11, 1999, as the 78th signatory. It was ratified on April 27, 2007, when the Croatian Parliament passed the Law on the Ratification of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Zakon, 2007). As a full member, the Republic of Croatia aimed to reduce greenhouse gas emissions by 5 % compared to 1990 levels in 2008-2012. In the Republic of Croatia, they even managed to exceed the goals of the first period by reducing emissions by 17.3 % compared to 1990. As part of the amendments to the Kyoto Protocol in Doha in 2012, the goal for the Republic of Croatia in the second commitment period (2013-2020) was to achieve a 20 to 30 % reduction in greenhouse gas emissions, compared to 1990, together with the EU, EU members and Iceland (Vlada RH, 2015).

Furthermore, the Paris Agreement was ratified in the Republic of Croatia on May 24, 2017, and entered into force on June 23, 2017. Within the framework of the Paris Agreement, the

Republic of Croatia is obliged to carry out a national inventory of greenhouse gases and a national statement on climate change and, together with other member countries, participate in achieving the goal of reducing greenhouse gas emissions by at least 40 % by 2030 (MINGOR, 2018). As part of the European Green Deal, the Republic of Croatia adopted the Law on Climate Change and Protection of the Ozone Layer as the first strategy to prevent greenhouse gas increase in the atmosphere and achieve climate neutrality by 2050 (Strategija, 2021). The Croatian Parliament adopted the Law in December 2019, and it "determines the competence and responsibility for mitigating climate change, adapting to climate change and protecting the ozone layer, documents on climate change and protecting the ozone layer, monitoring and reporting on greenhouse gas emissions, the system of greenhouse gas emissions trading, aviation, sectors outside the greenhouse gas emissions trading system, Union Register, ozone-depleting substances and fluorinated greenhouse gases, financing of climate change mitigation, adaptation to climate change and protection of the ozone layer, information system for climate change and protection of the ozone layer, administrative and inspection supervision" (Zakon, 2019). Accordingly, in 2020, the Croatian Parliament adopted the Climate Change Adaptation Strategy in the Republic of Croatia for the period up to 2040 with a view to 2070 (Strategija, 2020), which describes in detail the goals and measures that must be taken in the fight against climate change.

2.2. MINIMIZING THE IMPACT OF FOOD PRODUCTION ON THE ENVIRONMENT

The massive increase in the population caused a greater demand for food, precisely significant demand for food production and consumption. In order to meet this demand, it is estimated that crop production must double or increase by at least 70 % by 2050. The increased demand for food also significantly affects the environment because the increase in food production leads to notable use of energy and resources in the food supply chain (FSC) (Alhashim et al., 2021). Food supply chains are complex and involve several activities that directly or indirectly affect the environment. For instance, animal-sourced food production includes the production of animal feed, milk, meat, and eggs, animal slaughter, and manure and waste disposal. While in the case of products of plant origin, production includes emissions from soil, use of agricultural vehicles, production of fertilizers and pesticides, processing, transport and waste. All these activities emit greenhouse gases and affect climate change (Karwacka et al., 2020). In addition, according to data published by the Food and Agriculture

Organization of the United Nations (FAO), about 1.3 billion tons of food produced for human consumption worldwide are lost or wasted annually in food supply chains. That is why attention should also be paid to reducing waste if we want to decrease the impact of food production on the environment (Nicastro and Carillo, 2021).

Life cycle assessment (LCA) is a methodology that has been used since the 1960s to assess product footprints, i.e. the negative impact of products on the environment, taking into account the entire product life cycle, following the product from "farm to table". It is used to assess the impact of a whole range of products, from plant to animal, whereby the production of products of animal origin consumes more resources (land, water, energy) and has a more significant impact on biological pollution and contributes to ecosystem degradation. LCA analysis calculates the ecological footprints of products, the most important of which are the carbon footprint (CF), water footprint (WF), nitrogen footprint and energy footprint. Determining the ecological footprints of food can contribute to reducing greenhouse gas emissions by following the concept of sustainable development (Alhashim et al., 2021; Karwacka et al., 2020). Therefore, the results of LCA studies can be helpful to people involved in making or improving new policies in the food and agricultural sector, farmers, and politicians who develop sustainable production and policies in order to reduce the negative impact of food production on the environment (Alhashim et al., 2021). LCA is internationally standardized by the ISO 14040:2006 and ISO 14044:2006 norms and can be applied to agriculture and food production through 4 main phases:

1. Defining the goal and scope of the research - a critical step in conducting LCA
2. Life cycle inventory, LCI – includes input (consumption of energy, water, raw materials) and output (by-products, emissions of greenhouse gases into water, air, land and waste) units
3. Life cycle impact assessment (LCIA) – refers to the assessment of possible environmental impacts and includes classification, characterization and verification
4. Life cycle interpretation - refers to identifying key problems, verifying information, and making conclusions and recommendations for conducting research (Alhashim et al., 2021; Vidović-Popek, 2018).

2.2.1. Carbon (CO_2) footprint

"Carbon footprint is the amount of carbon dioxide (CO_2) emissions associated with all the activities of a person or other entity (e.g., building, corporation, country, etc.). It includes direct emissions, such as those that result from fossil-fuel combustion in manufacturing, heating, and transportation, as well as emissions required to produce the electricity associated with goods and services consumed" (Selin, 2022). The term carbon footprint has been used for decades, and it first appeared in the 60s of the last century, when more and more attention was paid to climate change and its impact on the environment. The carbon footprint of food includes the emissions of all greenhouse gases from the entire life cycle of the product, which includes the production, transportation, storage, cooking, throwing and disposal of the product (Karwacka et al., 2020; Naresh Kumar and Chakabarti, 2019). CO_2 is the gas that has the most considerable contribution to climate change (74.4 % of total emissions). However, other gases such as methane (17.3 %), nitrous oxide (6.2 %), and fluorinated hydrocarbons (2.1 %), despite the fact they have a lower contribution, are much more potent gases and cause greater warming, which significantly affects climate change. Their emissions are also included in the carbon footprint (Ritchie et al., 2020). Therefore, they are converted into a standard unit called the "equivalent" of carbon dioxide to monitor and compare carbon footprints more easily (CO_2 eq) (Karwacka et al., 2020). CO_2 eq is calculated by multiplying the mass of the greenhouse gas with its global warming potential (GWP). GWP is accepted by the IPCC, and it indicates the amount of warming that one ton of gas would create relative to one ton of CO_2 over a 100-year timescale. Figure 2 shows the GWP value for greenhouse gases relating to carbon dioxide. For example, the GWP of methane is 28, meaning that 1 kilogram (kg) of methane causes 28 times more warming; and 1 kg of nitrous oxide causes 265 times more warming than 1 kg of carbon dioxide (Ritchie et al., 2020).

The carbon footprint plays a significant role in minimizing environmental impact of the food system. It enables policymakers, companies, manufacturers and other stakeholders to identify critical points in the food production chain and directs them to identify ways to save energy consumption (Naresh Kumar and Chakabarti, 2019).

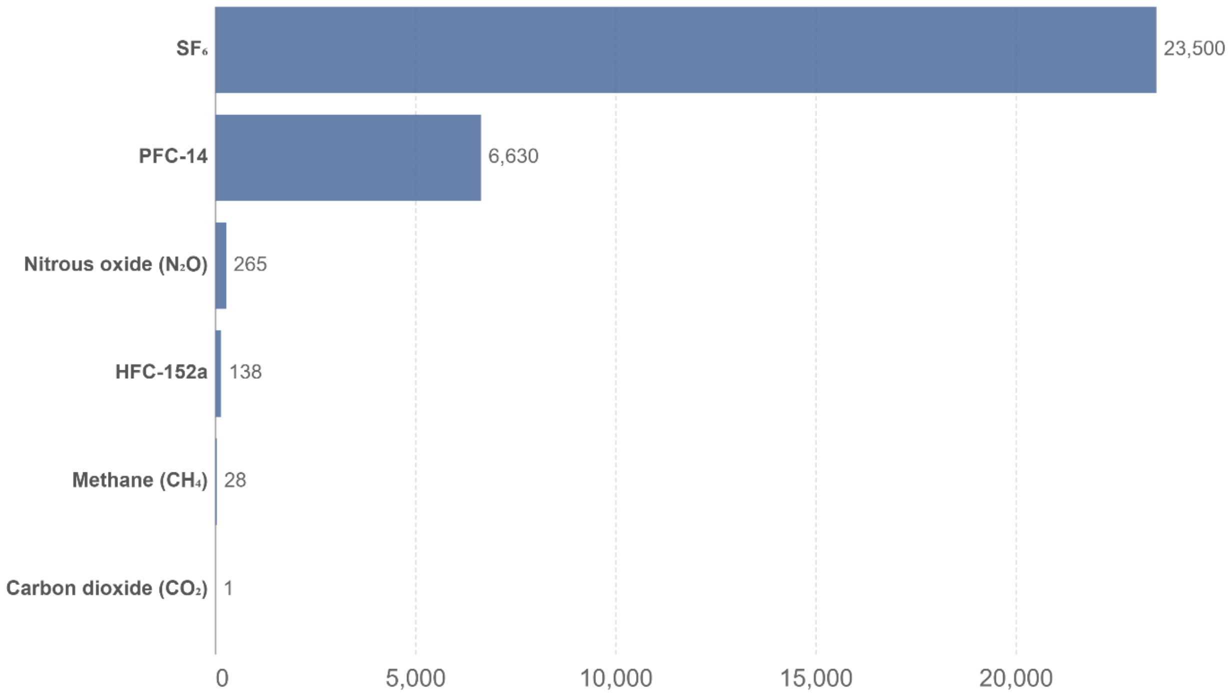

Figure 2. Global warming potential of greenhouse gases over 100-year timescale (Ritchie et al., 2020)

2.2.2. Virtual water and water (H_2O) footprint

The rapid population growth, the acceleration of economic development and the expansion of urban areas caused a greater demand for food and water. Therefore, the need for tools to better understand and reduce water scarcity has been developed. Two terms are used to understand water use: directly used water and virtual water. Directly used water refers to the water consumption we see; for example, by turning on the faucet, water comes out and is used for rinsing lettuce. Virtual water ("embedded water" or "indirect water") is a concept that refers to the water hidden in the products, services and processes that people buy and use every day. Thus, it is the water that a service or product consumes during its life cycle, enabling the creation of that product/service. It is related to its raw materials, production, consumption and region of export or import and is not visible to the end consumer; hence, it connects water, food and trade. In order to balance and conserve water, the virtual water strategy encourages water-scarce countries or regions to rely on water-using products from water-abundant countries/regions in trade (Xu and Li, 2020). The H_2O footprint refers to the amount of water the product contains and the freshwater used while obtaining products and services. Therefore, it is an indicator of direct and indirect water consumption and the impact of water consumption on the environment. The watermark is further divided into the blue, green, and grey. The blue water footprint refers to surface and groundwater consumption along the supply chain; the green water footprint refers to natural water consumption - the amount of rainwater that has evaporated or been directly used, and the grey water footprint refers to the volume of freshwater needed to dilute the pollutants (Karwacka et al., 2020; Xu and Li, 2020).

2.2.3. Food waste and food loss

Food waste occurs throughout the food supply chain, from farm to retailer distribution and, ultimately, to the consumers. In the food system, losses are associated with different methods, techniques, technologies and practices, but also with natural causes such as mould, pests, insects, temperature conditions, and humidity (Nicastro and Carillo, 2021). In households, the most common reasons for food waste are cooking too much food, food spoilage during storage, failure to use stored leftovers on time, expiration date, and buying too much food (Chinie, 2020).

Waste is characterized differently depending on where it occurs. "Food loss" results from problems in the production, storage, processing and distribution stages before the food reaches the consumer. On the other hand, "food waste" refers to food that is not spoiled and can be eaten but is consciously discarded during consumption or retail (Nicastro and Carillo, 2021; Chinie, 2020). Considering the projected increase in the population and the increase in demand for food by 2050, reducing and preventing waste is a big challenge. Therefore, to achieve it successfully, it is necessary to understand where to take preventive measures to reduce waste and to find out why it is created and what effect it has. According to data on food waste in the European Union, most waste is generated in households - 47 million tons, and in the processing sector - 17 million, which together amounts to 72 % of food waste in the EU. Food services are responsible for the creation of 11 million tons of waste (12 % of the total amount), manufacturing is responsible for 9 million tons, and retail and wholesale create 5 million tons of waste (Nicastro and Carillo, 2021). Furthermore, food production is responsible for 26 % of global greenhouse gas emissions, and 6 % of these emissions come from food that is never eaten and refers to food waste and loss in supply chains (Ritchie H., 2020b). For all these reasons, reducing food waste is part of the strategy of the EU Commission, which in 2016 established the EU Platform on Food Loss and Waste. This EU platform defines preventive measures and best practices for waste reduction and enables monitoring of progress. The ultimate goal of the EU platform is to halve food waste by 2030 (Chinie, 2020).

2.3. SUSTAINABLE DIET

Given that food production in the world is one of the main drivers of climate change and a significant cause of biodiversity loss and occupies about 38 % of the Earth's surface and about 70 % of the total consumption of freshwater, sustainable ways of eating are increasingly preferred (Martini et al., 2021; Polleau and Biermann, 2021). The FAO and WHO (2019) issued an official definition of a sustainable diet: "Sustainable Healthy Diets are dietary patterns that promote all dimensions of individuals' health and well-being; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable". They also have issued a list of 16 sustainable nutrition principles aimed at governments and other stakeholders to create national dietary guidelines; and divided the principles into three categories that sustainable nutrition must provide: environmental impact, health aspects and socio-cultural aspects. Dietary guidelines must be nationally or regionally specific; that is, each country or region must create customized national guidelines depending on the consumption, eating habits, and present diseases of a particular population to comply with the definition of sustainable nutrition (Martini et al., 2021). Therefore, a sustainable diet should be ecologically acceptable and rich in nutrients to ensure people's health.

The CO_2 and H_2O footprint of food give us information on how much a certain food affects climate change. Figure 3 shows actions in the food system that lead to greenhouse gas emissions (NO_2, CO_2 and CH_4). GHG emissions are shown per kilogram of food product, and the most important insight is the huge difference in greenhouse gas emissions of animal and plant-based foods. Beef, lamb and cheese have the highest carbon footprint, while plant-based foods have a lower carbon footprint. For example, we can single out the production of beef, which emits up to 60 kg of CO_2 eq per kg of product, and the largest part of the emission comes from farms and land use change (Ritchie, 2020a). The reason for such a high carbon footprint is also methane, which is a much stronger greenhouse gas than CO_2, and cows produce it through enteric fermentation (the production of methane in the stomachs of cattle). Pork and poultry have a significantly smaller carbon footprint since they are ruminants, i.e. do not produce methane through digestion and are fed less. So, to produce the same amount of food, it takes much less land to produce pork and poultry than beef (Clark et al., 2020). Also, 70 % greenhouse gass emissions comes from animal sector (EUR-Lex, 2020). Rice is a food of plant origin with a higher carbon footprint compared to other foods of plant origin. The reason for higher emissions is methane production by growing rice, which leads to a carbon footprint of about 4 g CO_2 eq per 1 kg of rice. In contrast to rice, vegetables, fruits and other plant-based food emit less than 2 kg CO_2 eq per kilogram of food (Ritchie, 2020a). Eating fish also has environmental consequences. Overfishing causes the decline of marine ecosystems and wildlife, and aquaculture destroys natural ecosystems, causing soil salinization and acidification, water pollution by pharmaceutical products, eutrophication and nitrification of wastewater (Polleau and Biermann, 2021).

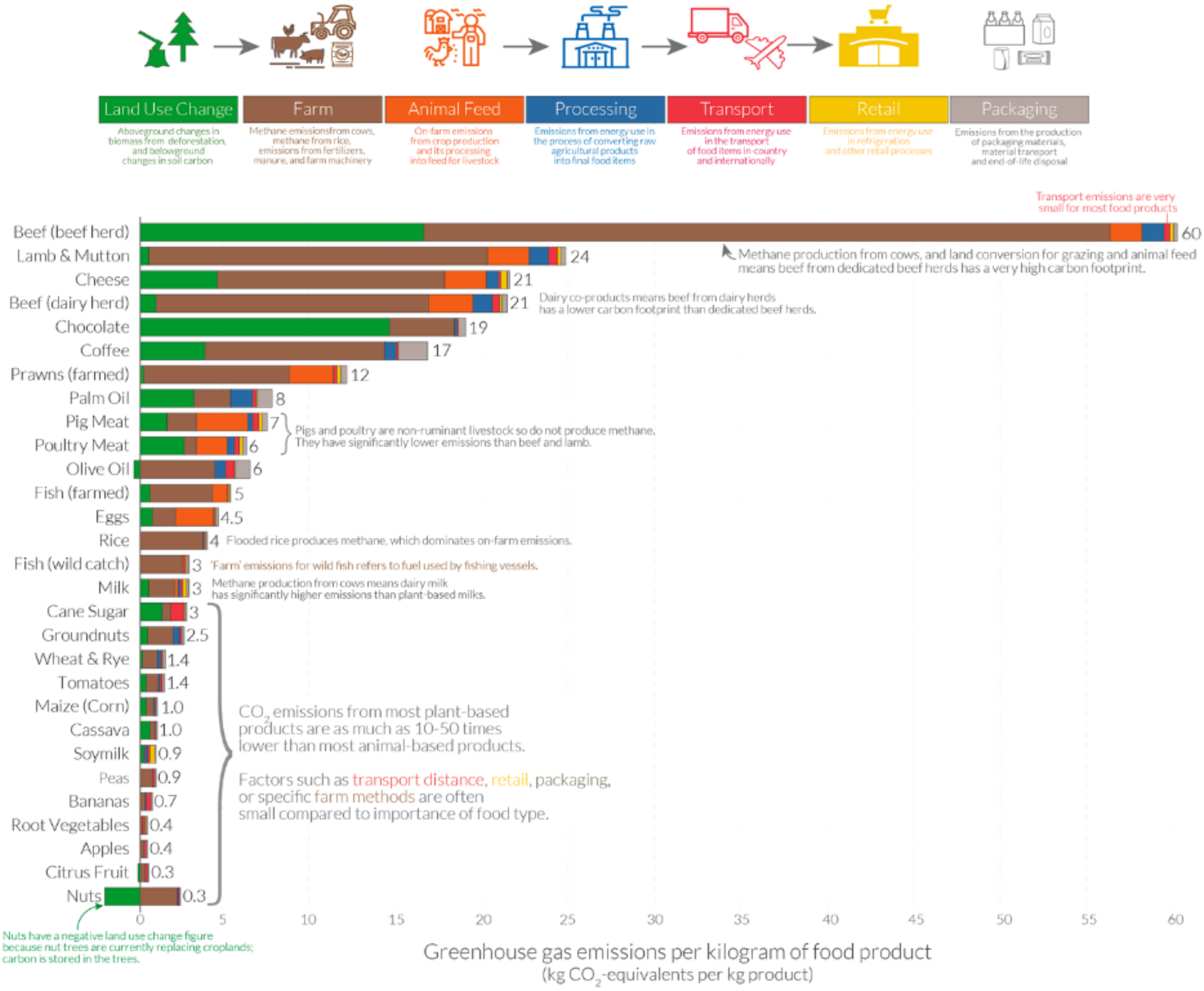

Figure 3. Greenhouse gas emissions across the supply chain (Ritchie, 2020a)

In addition, food of animal origin (meat, poultry, dairy products) is responsible for ¼ of humanity's water footprint. Thus, over 15 000 L of water is needed to produce 1 kg of beef, almost 6 000 L of water is needed to produce 1 kg of pork, and around 5 000 L of water is needed to produce 1 kg of cheese. In contrast, for the production of 1 kg of oats, around 2 500 L of water is needed; for the production of 1 kg of potatoes, broccoli and brussels sprouts, around 300 L of water is required. From these data, it can be concluded that what is valid for the CO_2 footprint is also valid for the H_2O footprint of foods - foods of animal origin have a much larger H_2O footprint than foods of plant origin (Marie A., 2022)

Sustainable nutrition is complex, and other aspects must also be considered when choosing products we eat. Food transport has a slightly lower impact on emissions during the product's life cycle. Most products' greenhouse gas emissions come from farm and land use changes compared to other parts of the product life cycle (Polleau and Biermann, 2021; Ritchie, 2020a). However, the globalization of the food industry and the demand for seasonal food throughout the year has led to an increase in food kilometres, i.e. kilometres that food travels from the point of production to the point of the final consumer (Naresh Kumar and Chakabarti, 2019). Vegetables and fruits produced out of season and air-transported emit more greenhouse gasses. Therefore, to reduce the carbon footprint of food, it is recommended to consume local/regional food. Food is considered local if its is purchased directly from producers within 100 km of where it is consumed (Aldaya et al., 2021). However, if it has been shown that local food production emits more greenhouse gases than the transportation of the same food from other places, such a product is less sustainable and has a higher carbon footprint (Naresh Kumar and Chakabarti, 2019). For example, if food is consumed out of season, it has a greater impact on the environment due to the greenhouse heating in which it is grown. Martinez et al (2020) stated that cucumber cultivated in a heated greenhouse has a higher carbon footprint, where electricity contributed approximately 68 % to the generated emissions. Also, in the UK, it is estimated that it is more sustainable to import lettuce from Spain during the winter months as a local production in the winter months increases greenhouse gas emissions by 3 to 8 times (Aldaya et al., 2021). Therefore, one should carefully consider and choose the foods that are consumed in order to stay within the framework of sustainability.

Furthermore, organic food production is also mentioned in sustainable nutrition; however, it has its positive and negative sides. The negative sides are higher emissions of greenhouse gases compared to conventional production due to the longer production cycle of, e.g. poultry and pork and lower crop yields. In contrast, the positive sides are using lower concentrations of pesticides on fruits and vegetables and promoting animal welfare (Polleau and Biermann, 2021).

From a health perspective, a diet without or with a reduced amount of meat is considered to have positive effects on health. The reason is that such a diet is primarily rich in vegetables, fruits and fibre and is associated with a lower risk for chronic non-communicable diseases such as obesity, type 2 diabetes and coronary heart disease (Polleau and Biermann, 2021). However, foods of animal origin contain numerous micronutrients of exceptional importance for human health, and eliminating these foods can cause deficiencies of some nutrients and consequently impair human health (Polleau and Biermann, 2021; Hyland et al., 2017). Therefore, sustainable nutrition is complex and should be viewed from several aspects, not in black and white. Instead of focusing on one group of foods, one should look at the entire diet. Hyland et al. (2017) pointed out in their paper that attention should also be paid to the amount of food consumed. Excessive food consumption is associated with higher emissions from food, which is significant not only for reducing the carbon footprint of the diet but also for addressing the obesity pandemic.

That is why nutritionists play a significant role not only in providing nutritional advice but in promoting environmental sustainability, reforming the food system and mitigating climate change. They are professionals with the qualifications and skills. In order to influence consumers, there are defined guidelines that nutritionists recommend to make people aware of a sustainable healthy diet:

- avoid over-consumption beyond caloric requirements
- limit intake of highly processed, nutrient-poor and over-packaged foods
- increase intake of plant-based foods
- eat seasonally and more locally produced foods
- minimise imported foods when local options are available
- adopt food waste minimization strategies
- connect with the local food system
- support sustainable food production practices (Dietitians Australia, 2021).

2.4. CLIMATE AND ENERGY-EFFICIENT SOCIALLY-ORGANIZED NUTRITION – EXAMPLES OF GOOD PRACTICE

Social responsibility in reducing pollution and waste is manifested in all human activities, including nutrition. Thus, a series of projects aims to encourage end-users to behave responsibly, and responsible societies start with socially-organized nutrition (such as kindergartens, schools, hospitals, and others). Examples of such projects are EU projects KEEKS and CLIKIS.

The project "KEEKS - climate and energy-efficient kitchens in schools" is an EU project that is the winner of the UN award "Momentum for Change", for which more than 560 projects worldwide were proposed. The project was initiated by the Institute for Future Studies and Technology Assessment from Berlin (German: Institut für Zukunftsstudien und Technologiebewertung, IZT), and the other project partners were ProVeg Deutschland e.V. (Berlin), Institute for Energy and Environmental Research (IFEU) (Heidelberg), Wuppertal Institute (Wuppertal), Netzwerk e.V. (Cologne) and Factor 10 (Friedberg). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety co-financed the project as part of the National Climate Protection Initiative. In the KEEKS project participated 22 school kitchens from the Cologne area. The goal of the project is to contribute to climate protection through school kitchens and education on how energy-efficient cooking can be easily achieved in school kitchens. Through the KEEKS project, they want to promote social services and environmental education by examining the impact of school meals on climate change, considering sustainability and supporting organic food, fair trade and MSC. They achieved this through the analysis of food use, energy consumption, availability and used kitchen techniques and all processes from procurement to waste disposal (KEEKS, 2020).

The project "CLIKIS NETWORK - Climate and energy-efficient kitchens in schools" is an EU project that continues the KEEKS project and has the same goal - to reduce the negative impact of school kitchens on climate change. The CLIKIS project was carried out from September 1, 2020, to December 31, 2022, in Elementary schools in Croatia and Estonia. Its purpose is to show that school kitchens can be energy efficient and that school meals can simultaneously be tasty, nutritious and affordable.

The first part of the project was related to school kitchens. All kitchen appliances produce carbon dioxide, and if the appliances are less efficient and consume too much energy, they negatively affect climate change. Therefore, devices for measuring electricity consumption have been installed in the kitchens of Elementary Schools in order to see how much effect school kitchens have on greenhouse gas emissions. After analyzing the results, recommendations were made for each school separately on measures to reduce the kitchen's greenhouse gas emissions.

The second part of the project was related to the meals themselves and reducing the carbon footprint of meals in school kitchens. Within that part of the project, school employees were educated about the climate impact of food production, processing and selection through a series of lectures. Firstly, the CO_2 footprints of the everyday meals in the elementary school were calculated, and ten climate-friendly and sustainable meals were created. In addition, the results of the CLIKIS project include the creation of posters for each school (Supplement 1) and booklet entitled "Climate and energy-efficient kitchens in Elementary Schools" (Supplement

2), the CLIKIS conference in the city of Sisak (Supplement 3) and competition that is called "CLIKIS and Healthy Meal Standard Chef's Academy" (Supplement 4) in which elementary school chefs competed in cooking climate-friendly meals of the CLIKIS project. The EU project financially supported EUKI - European Climate Initiative and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The partners involved in the implementation of the project are IZT (Institute for Future Studies and Technological Achievements), Wuppertal Institute, RED FORK and Estonian Green Movement.

3. EXPERIMENTAL PART

3.1 MATERIALS

The project was implemented in 9 elementary schools in Sisak, listed in Table 1.

Table 1. A list of Elementary schools in Sisak, the number of students and employees in the schools and meals served in a day

Elementary school	Number of students	Number of employees	Meals served/day
Braća Bobetko	444	73	432
Galdovo	300	52	293
Braće Ribar	630	67	509
Viktorovac	569	67	474
Ivana Antolčića Komarevo	102	28	101
22. Lipnja	510	81	435
Ivan Kukuljević	314	45	288
Budaševo-Topolovac-Gušće	284	60	273
Sela	192	32	179

The recommended value for the carbon footprint of the meal (CO_2 eq/meal) for an adult is 640 g CO_2 eq; and it was extracted from the scientific paper *"Assessing Indicators and Limits for a Sustainable Everyday Nutrition*" (Lukas et al., 2016). This value was then converted to the carbon footprint of a school meal for a 7-9 year-old child [2] to determine the climate impact of the meal.

The table of climate factors of food products from the KEEKS project created by the IZT (2019) was used to calculate the carbon footprints of school meals.

Meals were extracted from the "Recipe and menu book for cooked meals that provide 20 % daily value" (Gluhak Spajić and Kreš, 2022) for Elementary Schools of Sisak. This book of recipes contains 100 meals that are served in elementary schools, and chefs use these meals to make weekly menus. All meals presented in the "Recipe and menu book" are created by a nutritionist in a programme called "Healthy Meal Planner" (HMP) that was made by RED FORK company, owner of "Healthy Meal Standard" (HMS). HMS is a system for managing quality and food categories, present in all elementary schools in Sisak since 2016. HMS helps to organize the food system better, optimize costs, harmonize documentation with laws, rules and directives, create menus and regulations for special dietary needs depending on the selected categories and the needs of the kindergarten or school and create climate-sustainable meals.

"Healthy Meal Planner" contains one of the largest food composition databases in Croatia and is used to create diets and menus for HMS.

The diet in HMP contains recommendations for nutrient and energy values, which were created following "National guidelines for student nutrition in elementary schools" (Capak et al., 2013) issued by the Ministry of Health of the Republic of Croatia. The diet in Healthy Meal Planner contains: recommended energy and nutritional values (proteins, carbohydrates and fats) and recommended values of the carbon footprint of cooked meals of 20 % of the daily energy value (DEV) for school-aged children (7-9 years old) (Table 2). The "Healthy Meal Planner" also contains information on the mass of ingredients used for cooking the meal, the brand name of food products, allergens that the product contains (C) or are found in traces (T) in the product and mass of the meal, shown in Figure 4.

Table 2. Range of recommended energy and nutritional values and values of the carbon footprint of cooked meals of 20 % DEV for children 7-9 years old (Gluhak Spajić and Kreš, 2022)

Nutritional group data	Min	Max
Carbohydrates (g)	43.5	59.1
Proteins (g)	8.7	14.8
Fats (g)	11.6	15.3
Energy value (kcal)	348	394
Carbon footprint (g CO_2 eq)	0	376

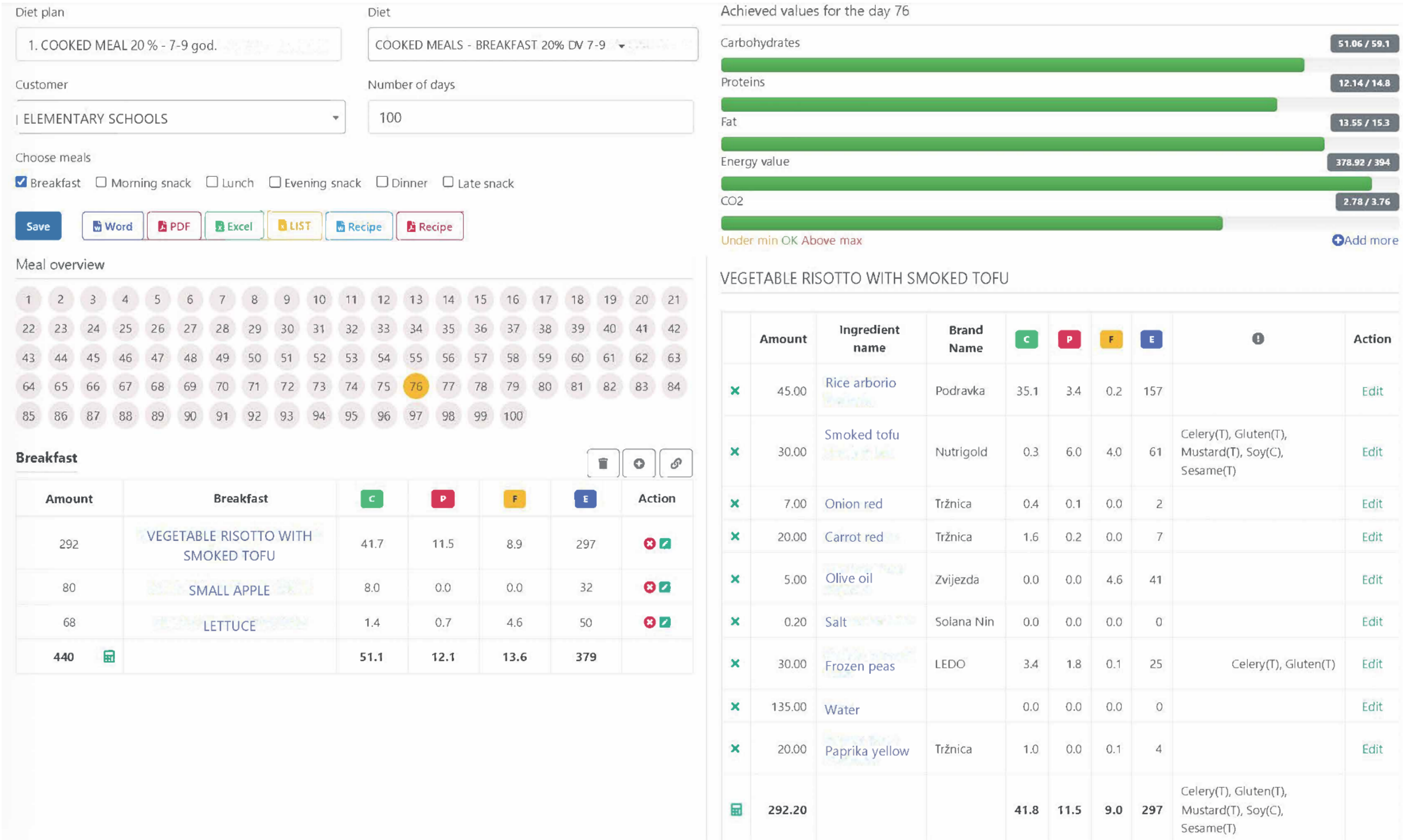

Figure 4. Healthy Meal Planner – cooked meal in menu with its mass, nutritional values, ingredients, the mass of the ingredients, allergens and brand name of the ingredient

Recommendations for acceptable electrical energy consumption of the kitchen devices in kWh were obtained from the IZT Institute (2021) (Table 3).

Table 3. Recommendations for acceptable electrical energy consumption of refrigerators and freezers depending on the size of the device (kWh/year) (IZT, 2021)

Kitchen device	Size of the device	kWh/year
Freezer	Big	1200
	Medium	800
	Small	600
Refrigerator	Big	250
	Medium	175
	Small	150

Measuring devices were used to measure the electrical energy consumption of kitchen appliances (refrigerators and freezers): Brennenstuhl PM231E, Voltcraft Energy Logger 4000, and Voltcraft model SEM4500 (Figure 5).

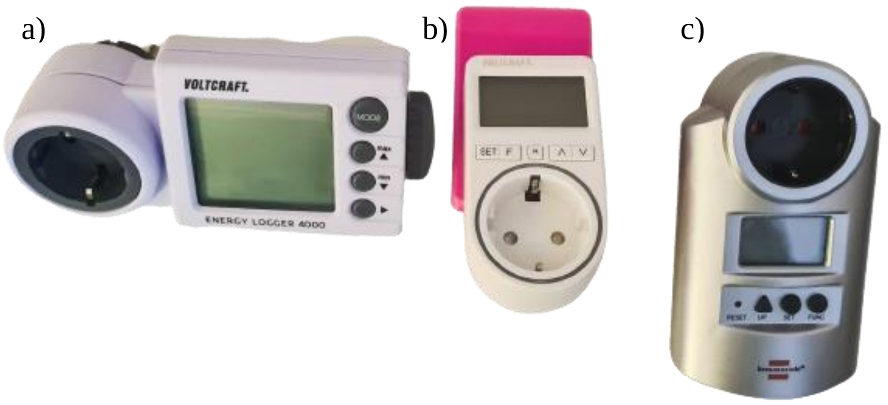

Figure 5. Devices for measuring the electricity consumption of kitchen appliances: a) Voltcraft Energy Logger 4000 (left); b) Voltcraft model SEM4500 (middle); c) Brennenstuhl PM231E (right)

3.2. METHODS

3.2.1. Calculation of the CO_2 footprint of a cooked meal (20 % DEV) for school-aged children (7-9 years old)

In order to create climate-friendly meals, the recommendation for the meal's carbon footprint must first be calculated. The recommended CO_2 footprint of a meal that provides 670 kcal for an adult is 640 g CO_2 eq (Lukas et al., 2016). In order to calculate the CO_2 footprint of a cooked meal (20 % DEV) for children, we first need to calculate g CO_2 eq/kcal (Table 4). Meal carbon footprint per kcal is obtained by dividing the meal carbon footprint by the energy value of the meal, presented in equation 1:

$$meal\ footprint\ per\ kcal\ \left(\frac{g\ CO_2\ eq}{kcal}\right) = \frac{meal\ carbon\ footprint\ (g\ CO_2\ eq)}{E_{meal}\ (kcal)} \quad [1]$$

Where;

Meal carbon footprint – presents the CO_2 eqvivalent per gram of the meal

E_{meal} – energy value of the meal in kcal

When the meal footprint per kcal (g CO_2 eq/kcal) is calculated, this value is multiplied by the energy value of the cooked meal to get the recommended value of the carbon footprint, presented in equation 2:

$$meal\ carbon\ footprint\ (g\ CO_2\ eq) = E_{meal}\ (kcal) * meal\ footprint\ per\ kcal (g\ CO_2\ eq/kcal) \quad [2]$$

Where;

Meal footprint per kcal – presents recommendation of carbon footprint per kcal of the meal

E_{meal} – energy value of the meal in kcal

An example of calculation using the previously mentioned equations is given in the Tables 4 and 5.

Table 4. Calculation of the carbon footprint per kcal (Lukas et al., 2016)

g CO_2 eq	kcal	g CO_2 eq/kcal
640	670	0.955223881

Table 5. Calculation of the carbon footprint of a cooked meal for a 7-9 years old child

Age	kcal/meal (20 % DEV)	g CO_2 eq/meal
7-9	348 - 394	0 - 376

Therefore, a meal for a 7-9 years old child must have a carbon footprint lower than 376 g CO_2 eq to be climate-friendly (Table 5).

The methodology used to calculate the carbon footprint of school meals comes from the proven KEEKS methodology. In order to be able to calculate the CO_2 footprint of a meal, it is necessary to have the following values:

- mass of the food/ingredient used to prepare the meal (kg)
- climate factor of food (kg CO_2 eq)

The carbon footprint (kg CO_2 eq) is calculated by multiplying the mass of the food/ingredient with the climate factor of the food, presented in equation 3:

$$meal\ carbon\ footprint\ (kg\ CO_2\ eq) = mass\ (kg) * climate\ factor\ (kg\ CO_2\ eq) \qquad [3]$$

Where;

Mass – presents mass of the ingredient in kg

Climate factor – presents climate impact of the ingredient in kg CO_2 eq

The ingredient mass is obtained from the recipes schools use to cook meals. It is expressed in grams and must be converted into kg, given that the climate factors are expressed in kg CO_2 eq. The carbon footprint can be calculated in two ways:

1. in the Healthy Meal Planner (a formula is entered in the program and the carbon footprint in kg CO_2 eq is automatically calculated by creating plans – Figure 4) or
2. in Microsoft Excel, as shown in Table 6.

The carbon footprint value of the school meal is then converted from kg CO_2 eq to g CO_2 eq for more straightforward interpretation of the results.

Table 6. Calculation of the carbon footprint of a school meal in Microsoft Excel

Meal name	Mass (g)	Product groups	GHG impact in CO_2 equivalents per ingridient (kg CO_2 eq)	GHG impact per ingridient * amount per meal (kg CO_2 eq)	GHG impact per ingridient * amount per meal (g CO_2 eq)	Notes	Sources
VEGETABLE RISOTTO WITH SMOKED TOFU				0.2319	231.9		
Rice arborio Podravka	45	Crop products	3.05	0.1373			KEEKS
Smoked tofu Nutrigold	30	Alternative products	1.2	0.0360			KEEKS
Red onion	7	Vegetables	0.25	0.0018			KEEKS
Red carrot	20	Vegetables	0.27	0.0054			KEEKS
Olive oil Zvijezda	5	Vegetable oils and fats	3.06	0.0153			KEEKS
Salt Solana Nin	0.2	Spices	0.19	0.0000			KEEKS
Pea frozen Ledo	30	Crop products	0.78	0.0234		peans green, frozen	KEEKS
Water	150		0	0.0000			KEEKS
Yellow paprika	20	Vegetables	0.64	0.0128			KEEKS
LETTUCE				0.0262	26.2		
Lettuce	60	Vegetables	0.2	0.0120			KEEKS
Sunflower oil Zvijezda	2.5	Vegetable oils and fats	2.24	0.0056			KEEKS
Olive oil Zvijezda	2.5	Vegetable oils and fats	3.06	0.0077			KEEKS
Salt Solana Nin	0.5	Spices	0.19	0.0001			KEEKS
Apple cider vinegar Ultra plus	2	Spices	0.41	0.0008		apple juice	NAHGAST
SMALL APPLE	80	Fruits	0.25	0.0200	20.0		KEEKS
IN TOTAL	**455**				**278**		

3.2.2. Measurement of electricity consumption of refrigerators and freezers

The measurement methodology used to calculate electricity consumption, i.e. CO_2 emissions, comes from the already verified KEEKS methodology in 8 steps:

1. List of devices at the location: it is necessary to list all devices that are on two-phase current and to request calculations of energy consumption from three-phase devices from the management of the organization
2. Selection of the most frequently used devices (which generally work the longest during the week, for example, refrigerators and freezers)
3. Recording the operating temperature and model of the device (essential for energy consumption because the devices are mostly set to the maximum temperature)
4. Plugging the measuring device into the socket on one side and the device on the other side
5. Energy consumption measurement over two weeks (optimal measurement time)
6. Data collection after two weeks (return to location)
7. Data analysis where initial and final data are compared
8. Writing reports and giving recommendations regarding the reduction of the CO_2 footprint and the use of best practices for increasing energy efficiency

Energy consumption of kitchen appliances was measured for approximately two weeks. The result of the measurement was energy consumption in kWh, which was read from the devices for measuring energy consumption (Figure 5). Energy consumption was then converted into annual value (kWh/year) based on the number of days the devices work in a year.

4. RESULTS AND DISCUSSION

School-aged children are in intensive growth and development, and in order for them to develop properly, grow, and be healthy, they need to have proper eating habits. Eating habits are primarily acquired at home. However, children spend a large part of the day at school, where they consume 20-70 % of their daily energy intake. Therefore, the school environment has a significant influence on children's eating habits. Schools are educational institutions, and as such, they should promote healthy eating habits that aim to prevent obesity and excess body weight and ensure a healthy and high-quality diet (Nogueira et al., 2021, Poličnik et al., 2021). In addition, schools are the right environment where children can learn what sustainable nutrition is and acquire sustainable eating habits that can be sustained throughout life and influence future generations (Nogueira et al., 2021). This is why the CLIKIS project was implemented in elementary schools in Sisak.

According to the National guidelines for children's nutrition issued by the Ministry of Health of the Republic of Croatia (Capak et al., 2013), children aged 7-9 years should consume 1740 kcal per day for girls and 1970 kcal for boys. Children in elementary schools in Sisak consume 20 % or about 65 % of the recommended daily intake of energy through 3 meals: breakfast – cooked or dry meal (20 %), lunch (35 %) and snack - dry meal (10 %). The city of Sisak recognized the need for children who eat only one meal at school to have cooked meals instead of constantly dry meals. That is why cooked meals are included in the morning in all schools in Sisak. Unfortunately, for some children, it is the only cooked meal of the day. Regular classes serve breakfast which provides 20 % of the daily energy value; in extended stay are served lunch, which provides 35 % of the daily energy value and snack, which provides 10 % of the daily energy value. However, a smaller number of children eat lunch and snack, unlike breakfast, which most children eat at school. That is why cooked meals served for breakfast were selected for optimization in this project. Also, as the devastating earthquake hit the city of Sisak in 2020, some schools were destroyed and moved to other school buildings. This pressured the schools to have children attend classes in shifts. As a result, they cooked meals both in the afternoon and in the morning for regular classes. Also, within the framework of HMS, we connected schools with local fruit and vegetable producers so that students receive local and seasonal foods throughout the year, which also reduces the carbon footprint of the meals.

The aim of this project was to analyze the carbon footprint of meals currently served in elementary schools in the city of Sisak, to optimize these meals and make ten nutritionally balanced meals with a low carbon footprint (Supplement 5), to measure the energy consumption of kitchen appliances connected to two-phase electricity and analyze the efficiency of the kitchen with recommendations how to make the kitchen more energy efficient.

The results are divided into two chapters:

- the first refers to the analysis of the carbon footprint of 5 omnivorous school meals served in elementary schools and creation of a 5 vegetarian school meals with a low carbon footprint
- the second refers to the electricity consumption of kitchen appliances connected to two-phase electricity (refrigerators and freezers)

In the first part, the carbon footprint of 10 school meals were calculated using Microsoft Excel and results are presented in Tables 7 and 8. Furthermore, the nutritional values and carbon footprints of the meals mentioned above were also shown through charts (Figures 6-14) created in Microsoft Excel.

In the second part of the results, the energy consumption results were calculated in Microsoft Excel and are shown in Table 9.

4.1. ANALYSIS OF THE CARBON FOOTPRINT OF 5 MEALS SERVED IN ELEMENTARY SCHOOLS AND THE CREATION OF A 5 MEALS PLAN WITH A LOW CARBON FOOTPRINT

Table 7. Nutritional values and carbon footprint of five omnivorous school meals

Nr.	Meal name	NUTRITIONAL VALUES				Carbon footprint (g CO2 eq)	Allergens
		Carbohydrates (g)	Proteins (g)	Fats (g)	Energy value (kcal)		
1	BULGUR AND EUROPEAN HAKE RISOTTO, TOMATO SALAD, PEAR	46.9	14.6	13.2	366	430	Gluten, Lactose, Dairy, Celery, Crustaceans, Fish, Molluscs
2	PASTA WITH MIXED MINCED MEAT, PICKLES, TANGERINE	46.8	15.3	14	377	443	Celery, Gluten, Mustard
3	COOKED CHICKEN AND POTATO IN CARROT SAUCE, PAPRIKA SALAD, APPLE	49.8	12.5	16	386	382	Celery, Gluten, Lactose, Dairy
4	RISOTTO WITH PORK, PAPRIKA SALAD, TWO TANGERINES	54.9	13.5	13.2	390	418	Celery
5	BEAN AND BEEF STEW, SCHOOL BREAD, TANGERINE	50.4	16.6	12.6	385	504	Gluten, Soy, Eggs, Dairy, Celery, Sesame, Lupine

The meals shown in Table 7 are taken from the "Recipe and menu book for cooked meals that provide 20 % daily value". The Table 7 contains data on the nutritional values (carbohydrates, proteins and fats), energy values, and the values of the carbon footprint of the meals. The energy value of the meals ranges from 366 to 390 kcal and is in accordance with the recommendations of the National guidelines for the nutrition of children in primary schools (Capak et al., 2013). These meals are omnivorous, i.e. they contain meat such as pork, beef and chicken, fish and fruits and vegetables. Several different meals were selected to see how the value of the carbon footprint changes in individual meals.

Table 7 shows that all dishes have a higher carbon footprint than recommended, i.e. higher than 376 g CO_2 eq (Table 5). As shown in Table 7, the bean and beef stew has the highest carbon footprint (504 g CO_2 eq), while the meal with chicken has the lowest carbon footprint (382 g CO_2 eq). The results of these calculations are influenced by individual ingredients. Reinhardt et al. (2020) showed the CO_2 footprints of various ingredients. The results of that study showed that beef has the highest carbon footprint, which is 13.6 kg CO_2 eq/kg food which correlates with the results of this study in which the beef meal has the highest carbon footprint. Reinhardt et al. (2020) presented several different CO_2 footprints for fish, depending on the method of cultivation and storage, ranging from 2.4 to 10 kg CO_2 eq/kg, which again correlates with our results showing that a fish meal has a very high carbon footprint of 430 g CO_2 eq. Furthermore, in Reinhardt's (2020) scientific paper, chicken and pork have a similar carbon footprint; for chicken, it is 5.5 kg CO_2 eq/kg and for pork is in the range from 4.6 to 5.2 kg CO_2 eq/kg. In our results, meal with chicken (number 3 in Table 7) has a lower carbon footprint than a pork meal (number 4 in Table 7), which may be caused by other ingredients of those dishes. Potatoes are another main ingredient in chicken meal, while pork meal contains rice. According to Reinhardt (2020), rice has three times the carbon footprint (3.1 kg CO_2 eq/kg) of potatoes (0.2 kg CO_2 eq/kg), which may be the reason for the larger carbon footprint of a meal with pork. In addition, the same results were confirmed by Volanti et al. (2021) and Martinez et al. (2020), who stated that dishes containing beef and fish (for example, hake) have a higher carbon footprint.

Table 8. Nutritional values and carbon footprint of five vegetarian school meals (modified omnivorous meals)

Nr.	Meal name	NUTRITIONAL VALUES				Carbon footprint (g CO_2 eq)	Allergens
		Carbohydrates (g)	Proteins (g)	Fats (g)	Energy value (kcal)		
1	BULGUR AND VEGETABLE RISOTTO, LETTUCE WITH CARROT, TWO TANGERINES	56	12.3	13.2	392	165	Gluten, Peanuts, Nuts, Sesame, Lactose, Dairy, Celery
2	LENTIL AND BUCKWHEAT BOLOGNESE, LETTUCE, TANGERINE	57.6	13	11.5	389	302	Gluten, Peanuts, Nuts, Sesame, Gluten, Celery
3	LENTIL AND EGGPLANT MOUSSAKA, BEETROOT SALAD, TANGERINE	58.1	14.6	12.7	395	193	Peanuts, Nuts, Sesame
4	VEGETABLE RISOTTO WITH SMOKED TOFU, LETTUCE, SMALL APPLE	51.1	12.1	13.6	379	278	Celery, Gluten, Mustard, Soy, Sesame
5	BEAN AND VEGETABLE STEW, BISCUIT CAKE WITH PRUNES	47.4	11.8	12.8	364	236	Celery, Gluten, Eggs, Dairy, Peanuts, Nuts, Sesame

Based on the results of the calculation of carbon footprint and the fact that several studies (Polleau and Biermann, 2021; Volanti et al., 2021; Clark et al., 2020; Martinez et al., 2020; Hyland et al., 2017) have indicated that food of animal origin has a greater negative impact on the environment than the food of plant origin. De Laurentiis et al. (2017) analysis has shown that reducing meat in dishes food would reduce the environmental impact of school meals in England. In order to optimize meals in Table 7, meat and fish were replaced by plant-based food rich in proteins. It has been proven that plant-based proteins are deficient in some amino acids. Nonetheless, they can be complementary to each other if properly combined. For example, combining legumes (deficient in methionine) and grains (deficient in lysine) provides all the necessary amino acids (Langyan et al., 2022; Qin et al., 2022). Plant-based protein sources that can replace animal-based protein sources are legumes such as soybean, beans, peas and chickpeas; pseudocereals such as quinoa, amaranth and buckwheat; chia seeds, and flaxseed (Langyan et al., 2022), but also tofu which is made from soy milk (Qin et al., 2022).

Meals shown in Table 8 are vegetarian meals, i.e. modified omnivorous meals, with their nutritional, energy and carbon footprint values. The energy value of vegetarian meals ranges from 364 to 395 kcal. It correlates with the recommendations of the National guidelines for the nutrition of children in primary schools (Capak et al., 2013). As stated earlier, the carbon footprint of a meal that provides 20 % DEV should not exceed 376 g CO_2 eq to have a lower negative impact on the environment. Table 8 shows that all vegetarian meals are climate-friendly because their carbon footprints are within limits. The meal with the highest carbon footprint of 302 g CO_2 eq, lentil and buckwheat bolognese (Supplement 6), still has a much lower carbon footprint than the recommendation. The meal with the smallest carbon footprint (bulgur and vegetable risotto), has a carbon footprint value approximately two times lower than the recommended value.

Figure 6. Average carbon footprint (g CO_2 eq) of the omnivorous meals and vegetarian meals (modified omnivorous meals)

According to Figure 6, which shows the carbon footprint plot for omnivorous and vegetarian school meals, there is a slight deviation of the mean value from the bias. Figure 6 shows a significant difference in the average carbon footprint of omnivorous meals and vegetarian meals. Specifically, omnivorous meals have a much higher median and overall carbon footprint than vegetarian meals.

In order to reduce the carbon footprint of school meals, it is necessary to change meal recipes. Figures 7 and 8 show the contributions of individual food groups to the carbon footprint of meals. As shown in Figure 7, meat and fish contributed the most to the carbon footprint of 5 omnivorous school meals. For instance, meal number 2 is pasta with mixed minced meat, pickles and tangerine (Table 7 and Figure 7). The most significant contributor to the carbon footprint in this school meal is minced meat. Nearly 225 g CO_2 eq comes from minced meat, and the rest, approx. 215 g CO_2 eq comes from other food groups (Figure 7). In order to decrease the carbon footprint of the meal, minced meat should be replaced with food with a lower carbon footprint. In this meal, to lower the carbon footprint, we replaced the minced meat with lentils and buckwheat as sources of protein. The optimized omnivorous meal i.e. vegetarian meal, lentil and buckwheat bolognese with lettuce and tangerine is listed in Table 8 and Figure 8 under number 2. Figure 7 and 8 show how the carbon footprint of school meal dropped from 443 g CO_2 eq to 302 g CO_2 eq, which is 141 g CO_2 eq less and within recommendations. We also changed the side dish. We replaced the pickles with lettuce, because there was a lack of fats in the vegetarian meal. Lettuce is seasoned with olive oil which increases the content of fats in the meal. Also, the pickles' carbon footprint is 1.60 kg CO_2 eq per kg of food, and lettuce is 0.20 kg CO_2 eq per kg of food. The data show that the value of the carbon footprint of the pickles is higher than the carbon footprint of the lettuce due to processing, the use of sugar as an ingredient and the packaging of pickles in a glass (IZT, 2019). All these processes additionally consume energy and increase the carbon footprint of food. Although without changing the side dish, the carbon footprint of this vegetarian meal would still be lower due to the removal of meat.

Bean and beef stew with school bread and tangerines, listed under number 5 in Table 7 and Figure 7, can serve as another example. By removing beef which contributes the most to the carbon footprint of the meal (Figure 7), we created a vegetarian meal (vegetable stew) in which the carbon footprint was reduced by 260 g CO_2 eq. This vegetarian meal, bean and vegetable stew with biscuit cake, is shown under number 5 in Table 8 and Figure 8. This meal was a bit complicated to optimize. By eliminating the beef, proteins were compensated by increasing the amount of beans in the meal and adding peas which also gave the stew a little different and better taste. Bread and tangerines did not meet the nutritional needs of the meal in combination with the bean and vegetable stew and were replaced with a biscuit cake with prunes. Biscuit cake with prunes has a higher energy value and carbohydrate content than the combination of bread and tangerines. Adding the biscuit cake to the meal ensured that the nutritional and energy value of the meal was in line with the recommendations.

We also added a new ingredient to the school meals, which is not very common for schools in Sisak. That ingredient is smoked tofu used in meal number 4 as a substitute for pork (Tables 7 and 8). Tofu and pork belong to the *meat, fish, eggs and alternative food* group. Figure 7 shows that pork has a significant contribution to the meal's carbon footprint (meal nr. 4), while Figure 8 shows that tofu has a smaller contribution to the carbon footprint (meal nr. 4). So, by replacing pork with tofu, the carbon footprint is reduced by a third.

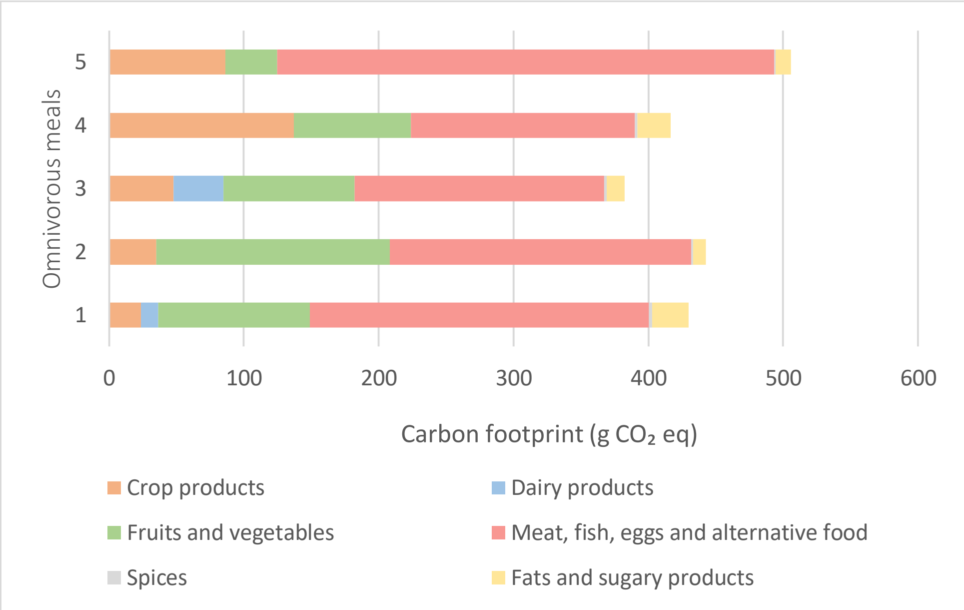

Figure 7. Contribution to the carbon footprint of a specific food group to five omnivorous school meals

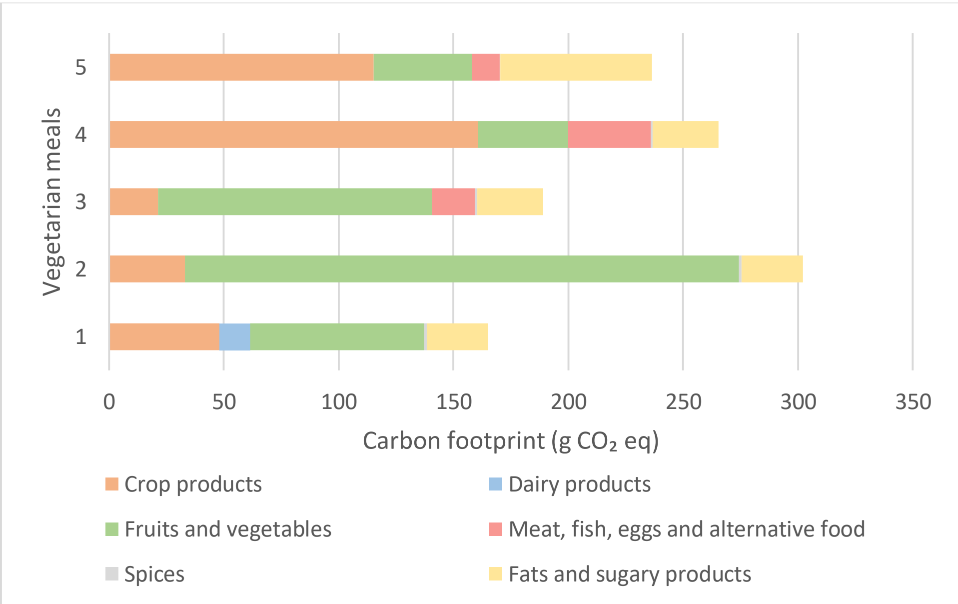

Figure 8. Contribution to the carbon footprint of a specific food group to five vegetarian school meals (modified omnivorous meals)

Until now, no one has analysed school breakfasts and their impact on climate change. Nevertheless, Volanti et al. (2021) studied the climate impact of school meals in Italy. There is a difference between the energy value of lunches and our meals which provide 20 % of the daily value, but we can still make a comparison. Namely, school lunches with meat, like pasta with meat and vegetables, had a carbon footprint of almost 1000 g CO_2 eq, while vegetarian lunch, pasta with vegetables, had a carbon footprint of less than 250 g CO_2 eq. Meal with meat has four times higher carbon footprint than a vegetarian meal. Their results can be compared with our results, where pasta with mixed minced meat (Table 7) had a higher carbon footprint than vegetarian pasta – lentil and buckwheat bolognese (Table 8). Dahmani et al. (2022) analysed the carbon footprint of school lunches in France. Their results show that vegetarian school lunches emitted 0.9 kg CO_2 eq on average, while a non-vegetarian lunch emitted 2.1 kg CO_2 eq. This is consistent with our results, where all omnivorous meals had a higher carbon footprint than vegetarian meals (Figure 6). Benvenuti et al. (2022) assessed the carbon footprint of vegan, vegetarian and omnivorous menus for primary schools in Italy. Their school meal analysis is aligned with ours. Some of their first-course vegetarian meals that fit our recommended energy values (Table 2) have a lower carbon footprint. These meals are pasta with tomato sauce and mozzarella cheese which emits 298.30 g CO_2 eq, dumplings with tomato sauce which emits 254.60 g CO_2 eq and rice with vegetables which emit 262.19 g CO_2 eq.

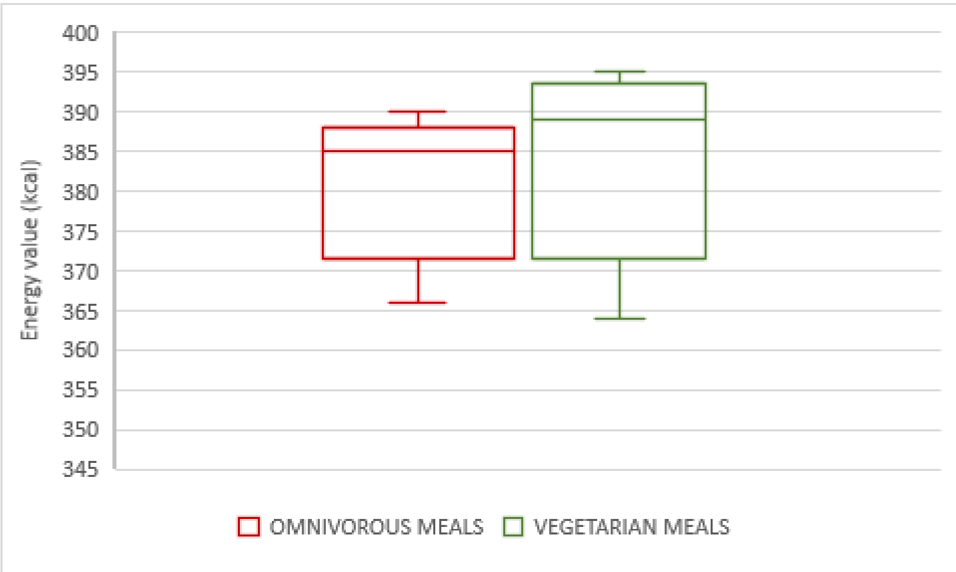

Figure 9. Average energy value (kcal) of omnivorous school meals and vegetarian (modified omnivorous) school meals

Figure 9 shows a box and whisker plot for the energy value of omnivorous meals and vegetarian meals. The medians and distribution of omnivorous and vegetarian meals are similar. Vegetarian meals have a slightly higher enery values than omnivorous meals. The energy values of both follow the recommendations according to which cooked meal provides 20 % of the daily energy value, and these energy values are shown in Table 2.

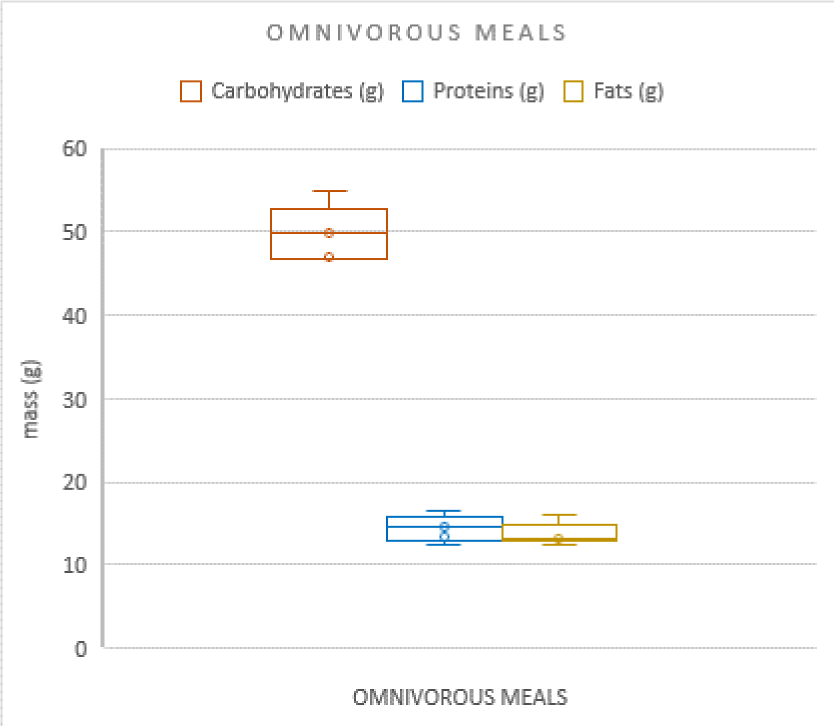

Figure 10. Average values of macronutrients (g) in omnivorous school meals

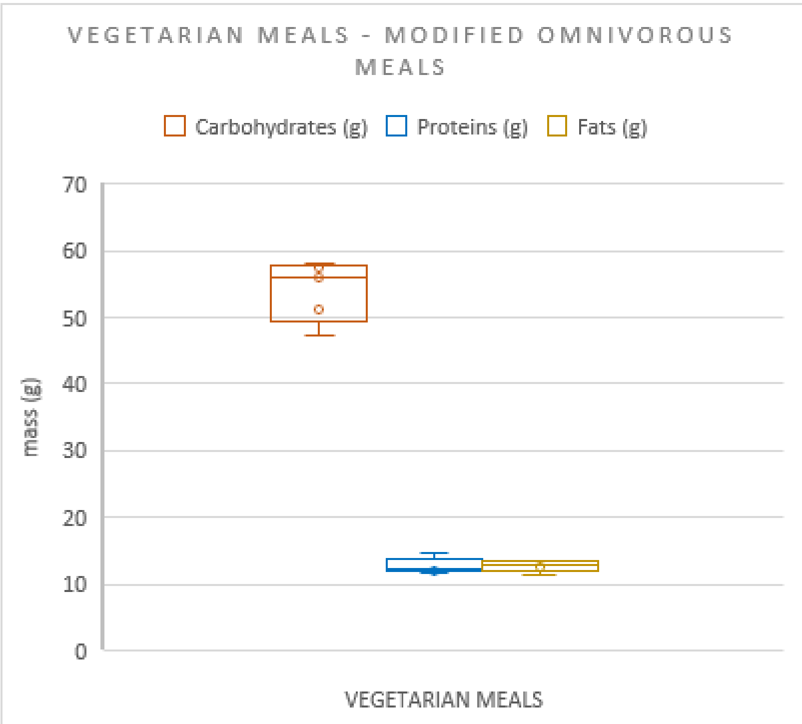

Figure 11. Average values of macronutrients (g) in vegetarian school meals, i.e. modified omnivorous meals

Figures 10 and 11 show a boxplot for the macronutrients (carbohydrates, proteins and fats) of omnivorous school meals and vegetarian meals. As we can see, vegetarian meals have a higher proportion of carbohydrates than omnivorous meals, which means that carbohydrates in vegetarian meals contribute more to the energy value of the meal. In comparison, average values of proteins and fats are slightly higher in omnivorous meals. However, both omnivorous and vegetarian meals have recommended values of macronutrients and are in accordance with Table 2. Therefore, vegetarian meals, which were created from omnivorous meals by replacing foods of animal origin with foods of plant origin, provide similar average values as omnivorous meals, and there is no significant difference in individual macronutrients.

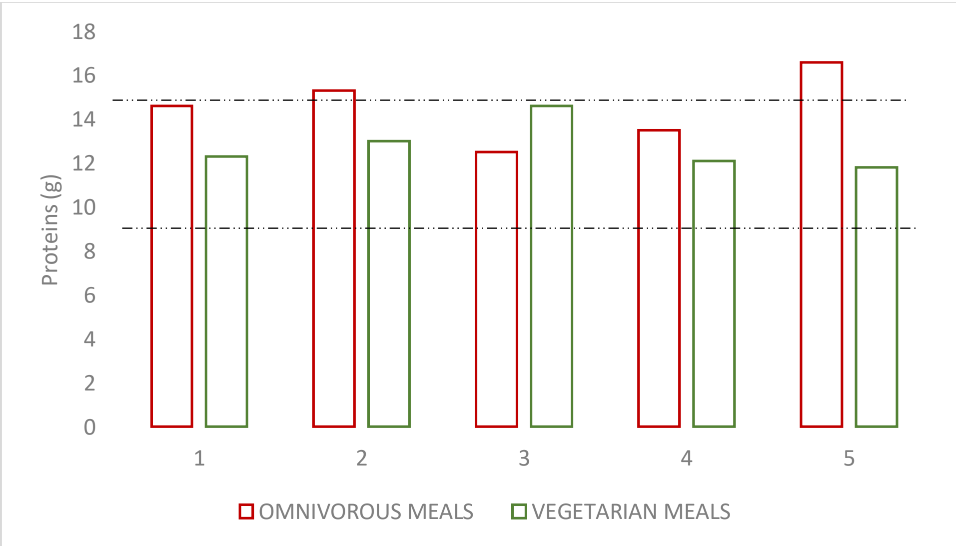

Figure 12. Protein (g) content in omnivorous and vegetarian meals with lines representing protein recommendations

According to Figure 12, which represents the amount of protein (g) in omnivorous and vegetarian meals, all vegetarian meals are in accordance with the recommendations shown in Table 2. Protein recommendations from Table 2 are presented on the graph with two lines representing the minimum and maximum values. The graph shows that 2 out of 5 omnivorous meals have a slightly higher protein content. Besides that, only one omnivorous meal has lower protein content than the vegetarian meal. In contrast to our results, Dahmani et al. (2022) stated that protein content was high for all school lunches, i.e. non-vegetarian, vegetarian and even vegan lunches. Most of the lunches served in primary schools in Dijon cover daily protein needs in excess (> 100 %).

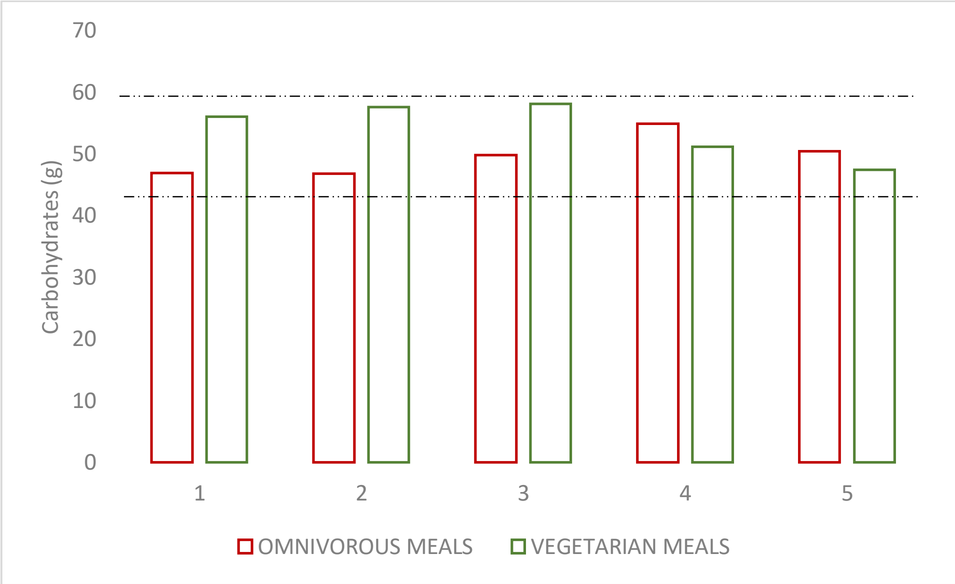

Figure 13. Carbohydrate (g) content in omnivorous and vegetarian meals with lines representing carbohydrate recommendations

Figure 13 shows the amount of carbohydrates in omnivorous and vegetarian meals, with recommendations indicated with two lines (minimum and maximum value) shown in Table 2. Ensuring enough carbohydrates was not an issue, given that carbohydrates are contained in fruits, vegetables and crop products. These are also foods that have a lower carbon footprint. Therefore, both omnivorous and vegetarian meals provide enough carbohydrates and meet the recommendation.

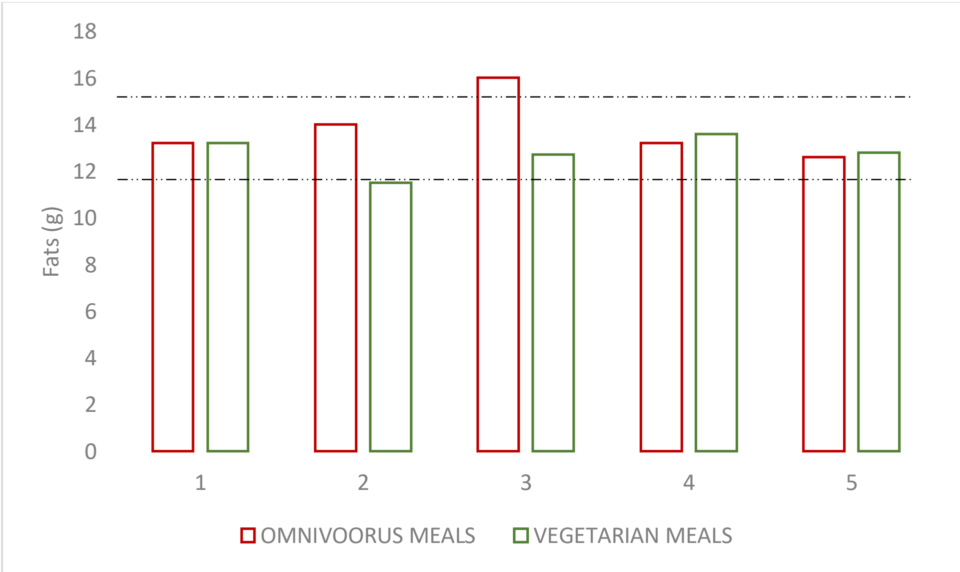

Figure 14. Fat (g) content in omnivorous and vegetarian meals with lines representing fat recommendations

Last but not least, is fat content shown in Figure 14. The first, fourth and fifth omnivorous and vegetarian meals provide a similar amount of fats, while the second and third omnivorous meals have higher fat content than vegetarian meals. Only one omnivorous meal has a slightly higher fat content than what is recommended and one vegetarian meal is at the lower limit. The lower limit is 11.6 g of fat, and the vegetarian meal nr. 2 (lentil and buckwheat bolognese) provides 11.5 g of fat, which is acceptable. Apart from that, other meals have a fat content in accordance with recommendations shown in Table 2. Since protein foods of animal origin naturally contain more fat than protein foods of plant origin, fats are provided by adding olive or sunflower oil to the meal. Considering that the goal is to reduce the carbon footprint, it is necessary to be careful which fats are added. For example, butter has a carbon footprint of 9.0 kg CO_2 eq per kg of food (Reindhart et al., 2020), so adding vegetable oils with a lower carbon footprint is recommended.

4.2. ELECTRICITY CONSUMPTION OF KITCHEN APPLIANCES CONNECTED TO TWO-PHASE CURRENT (REFRIGERATORS AND FREEZERS)

Refrigeration, cooking, processing and serving, dishwashing and other kitchen emissions are responsible for 34 % of emissions of school meals (Speck et al., 2020). The devices that were used to measure energy consumption (Figure 5) can only be used for appliances that use two-phase current. Given that most kitchen appliances in Sisak elementary schools, such as dishwashers, convection ovens and other large appliances, are connected to three-phase electricity, we could only measure the energy consumption of refrigerators and freezers. Kitchens and their equipment differ from school to school, and by analyzing each kitchen, we found out which are the main consumers of electricity. Below is Table 9, which contains the results of the measurements of refrigerators and freezers in elementary school Ivana Antolčića Komarevo. It is the smallest school in Sisak, with 102 students, and only one student does not eat at school. Therefore, the chefs cook 101 meals a day. Brennenstuhl PM231E, Voltcraft SEM4500, Voltcraft Energy Logger 4000 are the measuring devices used to measure the energy consumption of refrigerators and freezers in elementary school I. A. Komarevo.

Table 9. Electricity consumption of kitchen appliances in elementary school Ivana Antolčića Komarevo, Sisak

Device	**Device size**	**Measurement period** (days)	**Temperature** (°C)	**Energy consumption** (kWh/ year)
Freezer Gorenje FH13G	small	13	-25	614.9
Freezer Forcar GN 650 BT	big	13	-19	3832.5
Refrigerator Gorenje R60390DW	medium	13	+12	317.3
Refrigerator Forcar GN 650 TN	big	13	+5	822.7

The school has two freezers and two refrigerators for storing and cooling food. From Table 9, we can read the device models and their sizes, measurement period in days, the temperature of the device (°C) at the time of measurement and how much energy it consumes during the year expressed in kWh. None of the four devices has energy consumption within recommendations (Table 3). The recommendation for a small freezer is an energy consumption of up to 600 kWh, and the Gorenje FH13G, a small freezer, has an energy consumption of 614.9 kWh. The consumption of this device is only slightly above the recommended value, so we can classify it as a climate acceptable device. The optimal freezer temperature is -18 °C, and devices set to only 2 degrees colder consume approximately 10 % more electricity (Scharp et al., 2019). This small freezer was set to -25 °C, which is 7 degrees colder than the optimal value. This means that its consumption would be significantly below the recommended maximum value if it were set to the optimal temperature. The following device is a big Forcar GN 650 BT freezer with three times higher consumption than recommended (Tables 3 and 9). It is set to -19 °C, but it would be better to set it to -18 °C. Also, there may be other reasons for its high energy consumption. If the device consumes this much energy, it is inefficient and should be replaced with a newer, more efficient energy-class A device. This Forcar GN 650 BT freezer is energy-class E, and replacing such a device with a more efficient one can save energy consumption by 9 % (Scharp et al., 2019). The refrigerator Forcar GN 650 TN has approximately three times higher energy consumption than what is recommended in Table 3. This device is energy-class D, so the best option would be to replace it with a more efficient device, preferably energy-class A. Furthermore, the maximum recommended energy consumption for a medium refrigerator is 175 kWh per year. Gorenje refrigerator in Elementary School Komarevo consumes about 317.3 kWh, which is almost two times higher than the maximum value. This refrigerator is energy class A. The biggest problem is that it is set to +12 °C, which can impact food safety. Refrigerators must be set to the maximum of +4 °C and what applies to freezers also applies to refrigerators, i.e. if they are set to a two-degree lower temperature, energy consumption increases by 10 % (Scharp et al., 2019). Cause of such high energy consumption of cooling devices is that some were not appropriately maintained, leading to increased energy consumption. Accumulated ice on the cooling elements acts as insulation from the inside and retains heat. Dust on heat exchangers also has an insulating effect. Regular defrosting and cleaning cooling devices are thought to reduce energy consumption for freezing by around 10 % (Scharp et al., 2019).

Most cooling devices in elementary school Komarevo are placed against the wall, which leads to heat accumulation and additional heating of the device. Consequently, to reduce the devices' energy consumption, they must be placed at least 10 cm from the wall in colder rooms (Scharp et al., 2019). Also, given that this school has 102 students and contains the same number of cooling devices as schools with 300 or more students. The energy consumption of the kitchen would be greatly decreased if the number of cooling devices were reduced and the remaining devices were replaced with more efficient devices. Investing in a new and more efficient kitchen devices costs more initially, but it pays off more in the long run (Speck et al., 2020). Besides that, we analyzed the rest of the emissions from the kitchen. For cooking, they use an electric stove and a small convection oven that is the right size for their needs. Cooking is done on newer appliances, which are utilized efficiently. For dishwashing, they have one dishwasher (Colged tech steel 16-00), which is large enough for the number of meals being prepared. The issue is lots of hand rinsing and pre-rinsing with hot water, which results in high energy consumption for rinsing. Speck et al. (2020) emphasized that dishwashing is very energy-intensive, and starting the dishwasher when it is full is recommended as it saves about 1.20 % of greenhouse gas emissions. Other kitchen appliances used in elementary school Komarevo are one meat cutter, food choppers, kitchen mixer and other small appliances, which are used sparingly and their contribution to greenhouse gas emissions is negligible.

The limitation of this study is that we could only measure the energy consumption of devices that use two-phase current, i.e. cooling devices. Other devices, such as dishwashers and convection ovens, are also often used, but they are connected to a three-phase current, which we could not measure. The measurement was carried out in the fall; therefore, for more accurate results, it should also be carried out in other seasons to see the difference in electrical energy consumption concerning seasonality. Also, the kitchen has circuit breakers near the kitchen entrance but does not have an electric current meter. This is due to the school having solar panels on top of the building, and the electricity is run through the special meter, which is then split with a Croatian electric power distributor (HEP). In 2020, Sisak was hit by a strong earthquake, and some schools had to share the same building, which could also affect the measurement results.

This study is based on meals consumed by school children. It shows us valuable insights into the impact of school meals on climate change and how it is possible to create climate-friendly and nutritionally rich meals through small changes These results could also be helpful for policymakers regarding efficient socially-organized nutrition. The CLIKIS project was successful in that it has been able to identify recommendations for each school to optimize work in the kitchen and meal preparation. The food waste measurement was not the project's focus, but it would be the next step to increase sustainability since food waste also contributes to greenhouse gas emissions.

5. CONCLUSIONS

Considering the goal of the research and the obtained results, we can conclude the following:

1. This study uses actual meals prepared in schools, including school suppliers of food, and may be useful to policymakers regarding effective socially-organized nutrition
2. Previous findings that food of animal origin has a greater impact on carbon footprint and that food of plant origin has a lower carbon footprint have been confirmed. This study showed that by replacing foods of animal origin with foods of plant origin, the carbon footprint of school meals could be greatly reduced
3. Both omnivorous and vegetarian meals had macronutrients (proteins, fats and carbohydrates) and energy value in accordance with the recommendations of the National guidelines for children's nutrition in primary schools issued by the Ministry of Health. It proves that school meals can successfully be improved regarding environmental sustainability without affecting the growth and development of the children
4. Most refrigerators and freezers in school kitchens emit large amounts of greenhouse gases due to poor maintenance, incorrectly set temperatures and device inefficiency
5. The increase in greenhouse gas emissions from school kitchens is also contributed by the inadequate number and size of kitchen appliances, and activities such as washing dishes with hot water, which additionally consumes energy

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7. SUPPLEMENTS

Supplement 1: Example of one poster displayed in Schools

Supplement 2: Front page of the booklet "Climate and energy-efficient kitchens in Elementary Schools"

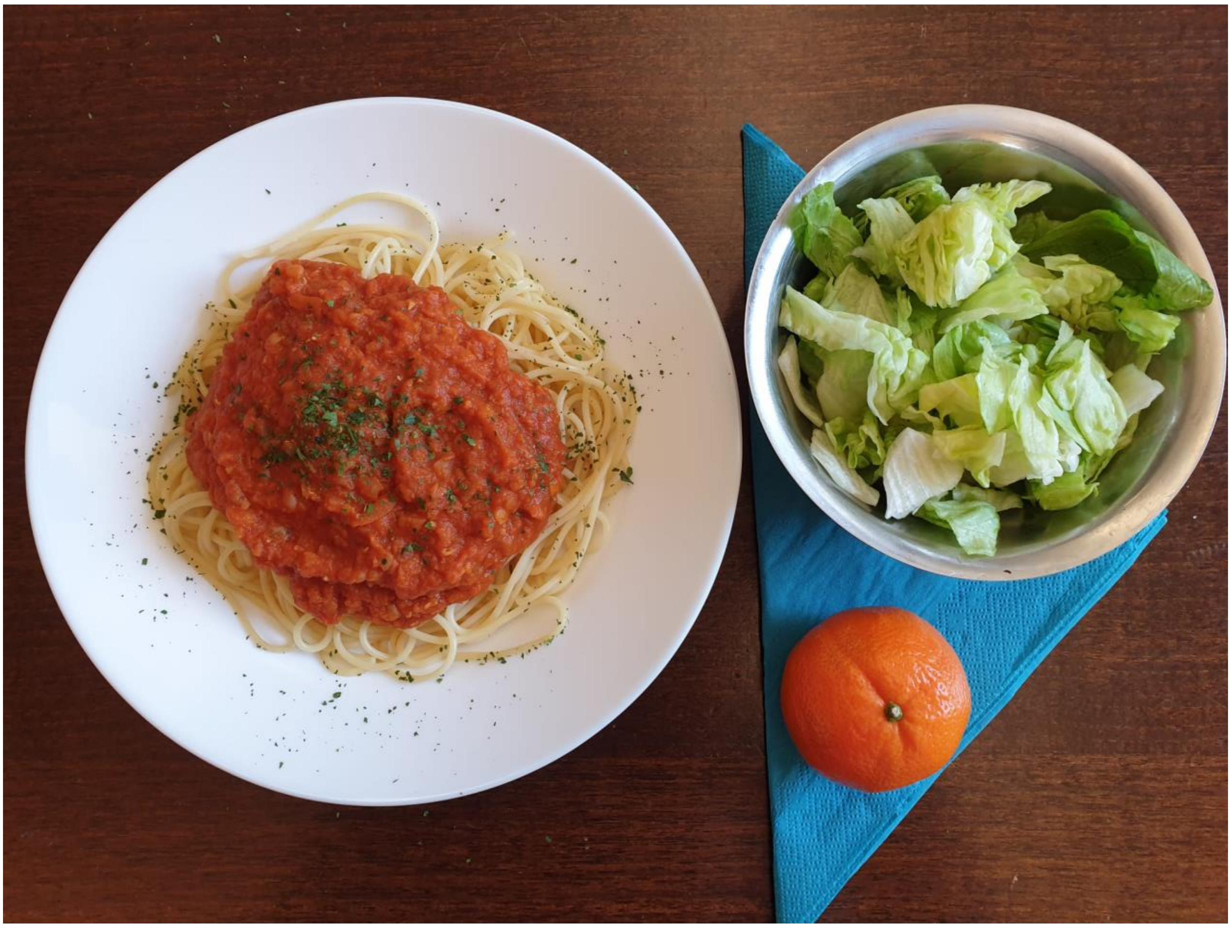
Supplement 3: Front page of the broschure for CLIKIS conference held in Sisak

Supplement 4: Poster for "CLIKIS and Healthy Meal Standard Chef's Academy" held in Elementary School Braća Bobetko, Sisak

Supplement 5: List of ten meals with low carbon footprint, their nutritive value and allergens

Nr.	Meal name	NUTRITIONAL VALUES				Carbon footprint (gCo2 eq)	Allergens
		Carbohydrates (g)	Proteins (g)	Fats (g)	Energy value (kcal)		
1	GREEN LENTIL AND VEGETABLE STEW, SCHOOL BREAD, APPLE	56.2	8.2	11.7	367	166	Celery, Gluten, Eggs, Soy, Dairy, Sesame, Lupine
2	BEAN AND VEGETABLE STEW, BISCUIT CAKE WITH PRUNES	47.4	11.8	12.8	364	236	Celery, Gluten, Eggs, Dairy, Peanuts, Nuts, Sesame
3	CHICKPEAS, BRUSSELS SPROUT AND SMOKED TOFU STEW, SCHOOL BREAD, SMALL APPLE	47.2	12.5	13	358	177	Celery, Gluten, Mustard, Soy, Sesame, Eggs, Dairy, Lupine
4	BAKED POLENTA WITH VEGETABLES AND SCRAPED BAKED CHEESE, LETTUCE, PLUMS	48.9	11.7	14.2	360	303	Gluten, Eggs, Dairy, Dairy, Lactose, Gluten, Dairy, Celery
5	LENTIL AND BUCKWHEAT BOLOGNESE, LETTUCE, TANGERINE	57.6	13	11.5	389	302	Gluten, Peanuts, Nuts, Sesame, Gluten, Celery
6	PASTA WITH CABBAGE, CHICKPEA FRITTER, LETTUCE, SMALL APPLE	56.7	11.1	12.2	389	151	Celery, Gluten, Eggs, Soy, Dairy, Sesame
7	VEGETABLE RISOTTO WITH SMOKED TOFU, LETTUCE, SMALL APPLE	51.1	12.1	13.6	379	278	Celery, Gluten, Mustard, Soy, Sesame
8	LENTIL AND EGGPLANT MOUSSAKA, BEETROOT SALAD, TANGERINE	58.1	14.6	12.7	395	193	Peanuts, Nuts, Sesame
9	PASTA WITH LEGUMES AND VEGETABLES, LETTUCE, TANGERINE	43.8	16.6	13.2	362	147	Gluten, Soy, Celery, Eggs, Dairy
10	BULGUR AND VEGETABLES RISOTTO, LETTUCE WITH CARROT, TWO TANGERINES	56	12.3	13.2	392	165	Gluten, Peanuts, Nuts, Sesame, Lactose, Dairy, Celery

Supplement 6: Meal no. 2 - lentil and buckwheat bolognese with lettuce and tangerine, carbon footprint 302 g CO_2 eq



DECLARATION OF ORIGINALITY

I (PATRICIJA KREŠ) declare that this master's thesis is an original result of my own work and it has been generated by me using no other resources than the ones listed in it.

Signature