Chapter N (please do not write anything in this line. Editors will annotate the chapter number)

**Life Cycle Assessment of seasonal meals: the case of school canteens**

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**Abstract**. School canteens may play an important role in promoting sustainable diets based on the selection of seasonal meals and nutritional values. In this study, the Life Cycle Assessment method has been applied to evaluate the environmental performance, in terms of global warming, related to the life cycle of four seasonal menus supplied to schools canteens. Furthermore, the aim is also to understand how environmental sustainability may be linked to strategic choices oriented to seasonal menus and nutritional values of ingredients. The functional unit is referred to “one seasonal menu delivered to a school canteen”, while system boundaries are defined including three different phases: 1) ingredients production and transport, 2) meals preparation, and 3) meals delivery. The results underscore that, in all the investigated menus, the ingredients production (phase 1) causes the main contribution to the impacts, followed by the cooking processes (phase 2). Furthermore, a high variability is identified when the impacts of ingredients are compared to their nutritional values, as well as an improvement in global warming performance is identified when seasonal food products are adopted. The study also points out the need for more specific frameworks aimed at helping decision-makers in choices regarding sustainable and nutritional balanced diets.

**Keywords.** School canteen, Life Cycle Assessment (LCA), food services, sustainable diet, agri-food, climate change.

# Introduction

The transition toward sustainable food systems represents a priority among the European policies, due to the need for reducing malnutrition and food poverty as well as improving food environmental performance (EC, 2022). With specific regard to environmental sustainability, food productions are responsible for significant impacts (Notarnicola et al., 2012), that are expected to further raise in relation to the increasing demand for food by 2050. Guyomard et al. (2012) highlighted the link existing between dietary patterns and the sustainability of food systems and production. Furthermore, various national documents, particularly in Europe (e.g., Italy and Germany), that provide food-based dietary guidelines, include recommendations on how to achieve sustainability in diets (FAO, 2022). Such recommendations commonly refer to the sustainability of the whole life cycle of food products, thus including, production, packaging, transport and consumption (e.g., CREA, 2019).

Schools and related food services may play a very important role in promoting sustainable diets (CREA, 2018). Indeed, school canteens may contribute to educating people about good nutrition and sustainable foods (e.g., by promoting sustainable healthy menus). For this reason, the design and preparation of a menu for school canteens has to consider the environmental impacts of meals and related ingredients, in addition to the nutritional values and seasonality. Considering the strong link between food, dietary habits, seasonality and environmental sustainability, there is an increasing interest, among the scientific community, in assessment methods able to capture this complexity. Among those methods, the Life Cycle Assessment (LCA) is considered the main approach used to evaluate the environmental sustainability of food productions and diets (Aldaya et al., 2021).

In this context, this study aims to assess the potential environmental impacts, through the LCA method, connected to the preparation of menus and related services for school canteens, focusing on the amount and nutritional value of meals and highlighting the role of strategic choices linked to seasonality.

# Material and methods

The potential environmental impacts of the menus provided to school canteens have been evaluated by applying the LCA method, according to the ISO 14040-44:2006. LCA is a standardized method used for the assessment of the potential environmental impacts of a product, process, or service throughout its whole life cycle, from raw materials extraction to the end-of-life (ISO, 2006a; ISO, 2006b).

## Goal and scope definition

LCA method has been applied to assess the environmental performance connected to the preparation and delivery of seasonal menus supplied by an Italian food service company to school canteens. In particular, the study investigates four menus (i.e., one per season), that are characterized by different ingredients and nutritional values. The scope is, on the one hand, to evaluate the environmental impacts of meals provided to school canteens focusing on a life cycle perspective, on the other, to understand how choices for diets based on the use of seasonal ingredients in menus and nutritional value are linked to environmental sustainability considerations.

The functional unit (FU) selected for carrying out the analysis was represented by “one seasonal menu delivered to a school canteen”. Choosing this FU permits the investigation of the four meals by considering the amount and nutritional value of each ingredient as well as their seasonality. Furthermore, system boundaries were defined including three main phases: 1) ingredients production and transport to the food service company; 2) meals preparation at the service company; 3) meals delivery to the school canteen. In addition, the packaging used for ingredients was considered in phase 1. Cut-off criteria include the end-of-life of the menu after consumption, assuming zero food waste.

## Inventory analysis

The Life Cycle Inventory (LCI) was built using primary and secondary data. Primary data were collected through direct interviews and questionnaires provided to the food service company, while secondary data were gathered using dedicated databases (e.g., Ecoinvent, WFLDB, etc.). Based on company communication, the main ingredients characterizing each of the investigated menus and the related nutritional values are reported in table 1.

Regarding the meal preparation phase and, in particular, the cooking through natural gas stoves, data were calculated considering the amount and heating capacity of the ingredients used in the menus as well as assuming specific cooking times per meal preparation. Furthermore, in phase 3, a distance of 25 km was assumed to transport the meals from the food service company to the different schools.

Table 1. Main ingredients used in the menus (company communication; Am = amount; NV = nutritional value; grey background: seasonal ingredients).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Autumn menu** | | **Winter menu** | | **Spring menu** | | **Summer menu** | |
| **Food category** | **Ingredient** | Am  (g) | NV  (kcal) | Am  (g) | NV  (kcal) | Am  (g) | NV  (kcal) | Am  (g) | NV  (kcal) |
| Cereal-based | Rice | 50 | 177 | - | - | 50 | 177 | - | - |
| Pasta | - | - | 50 | 186 |  |  | 50 | 186 |
| Breadcrumbs | - | - | 5 | 19 | 5 | 19 | - | - |
| Bread | 30 | 71 | 30 | 71 | 30 | 71 | 30 | 71 |
| Vegetable | Pumpkin | **50** | 10 | - | - | - | - | - | - |
| Cauliflower | - | - | 150 | 38 | - | - | - | - |
| Onion | 1 | 0 | - | - | - | - | - | - |
| Bean | 100 | 19 | - | - | - | - | 30 | **90** |
| Spinach | - | - | - | - | 40 | 11 | - | - |
| Lettuce | - | - | - | - | 40 | 7 | - | - |
| Radicchio | - | - | - | - | 15 | 2 | - | - |
| Tomato | - | - | - | - | - | - | 100 | **19** |
| Herbs | 1 | 1 |  |  | - | - | 1 | 1 |
| Garlic | - | - | - | - | 1 | 0 | 1 | 0 |
| Meat | Turkey | - | - | - | - | 50 | 53 | - | - |
| Fish | Codfish | - | - | 70 | 51 | - | - | - | - |
| Dairy | Cow milk | 5 | 2 | - | - |  |  | - | - |
| Ricotta | - | - | - | - | 5 | 7 | 5 | 7 |
| Parmesan | 2 | 8 | - | - | - | - | - | - |
| Butter | - | - | 5 | 38 | - | - | - | - |
| Fruit | Fresh fruit | 150 | 89 | 150 | 89 | 150 | 89 | 150 | 89 |
| Chicken egg | 60 | 77 | 10 | 5 | 10 | 13 | - | - |
| Other | Lemon juice | - | - | 8 | 3 | - | - | - | - |
| Tomato sauce | - | - | - | - | - | - | 15 | 3 |
| Olive oil | 10 | 90 | 6 | 54 | 15 | 135 | 15 | 135 |
| Sunflower oil | 5 | 45 | 5 | 45 | - | - | - | - |
|  | **Total** | **464** | **589** | **489** | **599** | **411** | **584** | **397** | **601** |

## Impact assessment

The Life Cycle Impact Assessment (LCIA) has been performed using the SimaPro 9.3 software (PRé Sustainability, 2021) and assessing the impacts related to global warming through the IPCC 2021 GWP100 method (IPCC, 2021). This impact category was selected being among the most adopted in LCA studies related to the agri-food sector (Dijkman et al., 2018).

# Results and discussion

Results reported in figure 1 show that the potential global warming impacts, of the four menus, are caused by phase 1 (mainly due to the production of ingredients), followed by the preparation of the meals (phase 2).

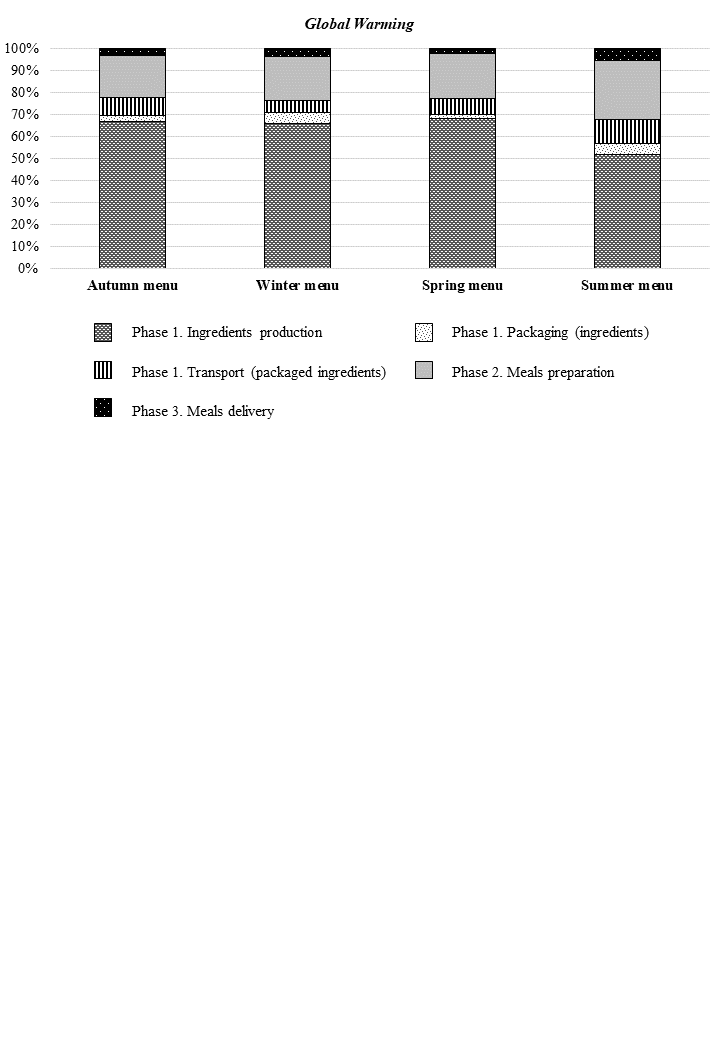


Fig. 1. Contribution analysis of the investigated seasonal menus and related life cycle phases (characterization results IPCC 2021 GWP100 method).

The global warming impacts caused by the four menus range from 1.08 kg of CO2 eq per FU in the spring menu, to 0.44 kg of CO2 eq per FU in the summer menu. In particular, the highest impact caused by the spring menu is due to turkey meat production which contributes 38.9% to the total global warming. Furthermore, the results highlight that the average contribution of the ingredients to global warming is about 66% in all the menus except for the summer menu in which the contribution to the impacts decreases to 51.7%. As reported in table 1, the summer menu is mostly based on seasonal ingredients,i.e., beans, tomatoes, and seasonal fresh fruit. Besides, as reported in table 1, the receipt used in this menu allows the nutritional value of the meals to be maximized (601 kcal), while reducing their amount as input (397 g), in comparison with the other analyzed menus. This points out that strategic choices oriented toward identifying a menu based on high nutritional value, seasonal ingredients and low amount of input, are fundamental to achieve environmental sustainability in diets. Regarding the other processes evaluated in phase 1, the contribution to global warming of the packaging materials ranges from 5.2% to 1.8%, and of the transport of packaged ingredients to the food service company range from 10.8% to 5.6%. In particular, the main impacts related to packaging are due to the polyethene (PE) film used for various ingredients (e.g., pasta, rice, etc.) and the steel cans used for olive oil. Furthermore, the impacts caused by the preparation of meals in phase 2 are strongly related to the type of meals and receipts characterizing each menu. Indeed, the main contribution is related to the boiling processes in the winter and summer menus, the frying process in the autumn menu and the oven cooking in the spring menu. The results also show that the delivery of meals to the schools causes a contribution to global warming ranging from 5.3% to 2.2%. In order to better understand the link between the environmental sustainability and the choices for seasonal ingredients in menus and nutritional value, the results are also discussed by comparing the global warming of the ingredients grouped by food category (as presented in table 1) and the related nutritional values, per each menu (figure 2). The main findings highlight a high variability between impacts and nutritional values, resulting in circumstances of trade-offs between the selection of more environmentally friendly ingredients or nutritional balanced menus. This is particularly true when meat or dairy products are included in the menus. Nevertheless, the results also underscore that high nutritional value and lower global warming impacts may occur when cereal-based products, vegetables and fruit represent the main portion in menus. Despite this, it is important to highlight that, these ingredients have a nutritional value lower than meat and dairy products. Regarding the link between seasonality and environmental impacts, as for the summer menu, environmental advantages in terms of global warming due to the use of seasonal vegetables and fruit are also identified in the other menus. For example, the cauliflower and grape in the winter menu cause a lower contribution to the impacts, compared to the other ingredients.

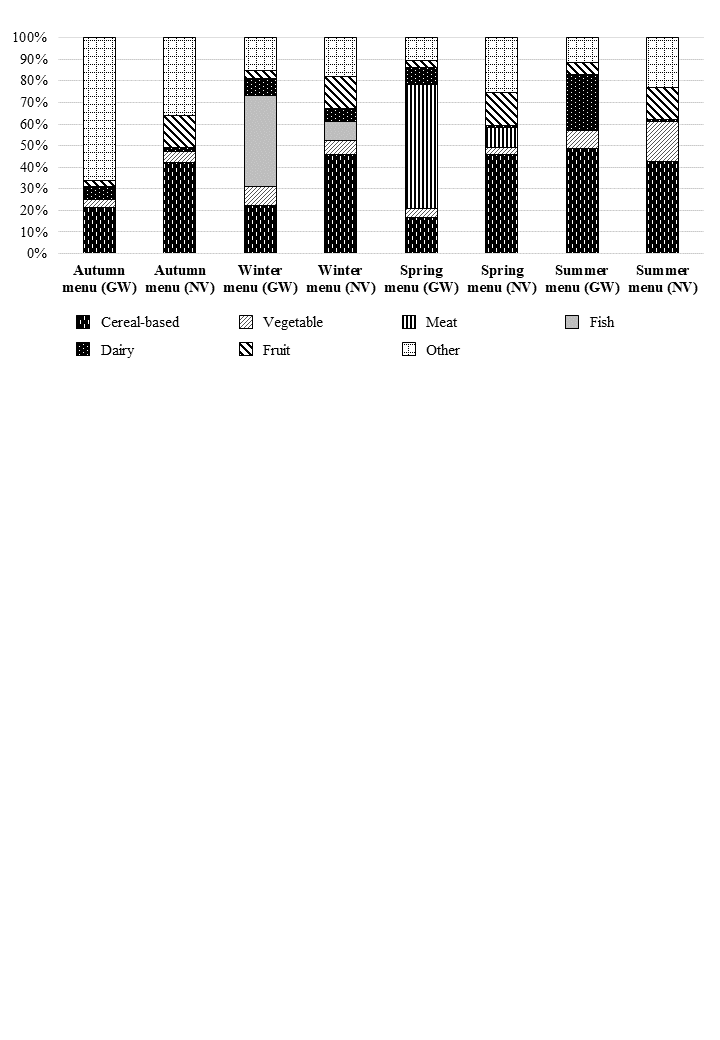


Fig. 2. Comparison between global warming (GW) and nutritional value (NV) per each menu.

# Conclusions

The aim of this study was to evaluate the environmental performance of four seasonal menus for school canteens, following a life cycle perspectives and including the phases from the production of the ingredients to the delivery of the meal to the school canteens. The analysis also aimed to evaluate the link between environmental sustainability and strategic choices for seasonal food products as well as nutritional values in diets. The main results highlight that the production of ingredients and the preparation of meals (i.e., cooking processes) are responsible for the higher global warming impacts, in all the menus investigated. The study also pointed out that trade-offs may occur between environmental impacts and nutritional value of the ingredients. This points the complexity in understanding how to move toward sustainable and nutritional balanced diets as well as the need for more dedicated frameworks for an integrated evaluation of the environmental sustainability and nutritional value of food products, as pointed out by McLaren et al. (2021). Lastly, the results confirm that low global warming occurs when seasonal ingredients are used in menus.

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