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# Sustainability and nutritional aspects of traditional dishes from the Friuli Venezia Giulia region, Italy: A true cost accounting evaluation

Federica Fiori [a,1], Alberto Bertossi [c,1], Stefania Troiano [b], Maria Parpinel [a], Francesco Marangon [b], Nicoletta Pellegrini [c,*]

[a] Department of Medicine, University of Udine, 33100 Udine, Italy
[b] Department of Economics and Statistics, University of Udine, 33100 Udine, Italy
[c] Department of Agricultural, Food, Environmental and Animal Sciences, University of Udine, 33100 Udine, Italy

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ABSTRACT

The agrifood system needs to be redirected towards a path of sustainable development in which tradition regains its rightful place and importance. True Cost Accounting (TCA) can support this transition by translating environmental impacts into monetary terms and highlighting the hidden costs of foods. The present research combines TCA with nutritional data of traditional dishes from the Friuli Venezia Giulia region (Italy) to assess their sustainability. Results show the dishes with the highest hidden costs are those with animal proteins (beef), while those with predominant vegetable proteins have generally lower hidden costs. Specific ingredients and portion sizes were found to influence the dish impact and should be considered when developing sustainable menus or guidelines. The present study can pave the way for further studies designed to consider actual environmental indexes of local origin foods and food preparations and to summarize them in a single economic indicator, such as true cost.

## 1. Introduction

In 2023, we crossed 6 out of the 9 planetary boundaries that circumscribe the safe space within which humanity can survive (Richardson et al., 2023). Progress towards the Sustainable Development Goals is not happening fast enough to achieve them by 2030 (United Nations, 2023) and one of the critical sectors is agribusiness (Campbell et al., 2017; FAO, 2022; Mbow et al., 2019). The way we produce and consume food is responsible each year for the depletion of 50 % of the planet's available resources (Global Footprint Network, 2024), the release of about one-third of greenhouse gases into the atmosphere (Crippa et al., 2021), extremely high use of water resources (Whitmee et al., 2015), and, along with many other elements, the increase of non-communicable diseases such as obesity and diabetes (Fanzo et al., 2022). Such negative externalities are an example of market failure (Michalke et al., 2023), as their cost, instead of being paid for by those who create them, is placed on society, totaling approximately $20 trillion/year (von Braun & Hendriks, 2023). In other words, we all pay for the consequences of damage caused by others, even though we are not the creators. Making the entire agri-food system operate within planetary boundaries while meeting the nutritional needs of the population requires an urgent transformation towards the promotion and adoption of healthy and sustainable diets (FAO, 2022; Ridoutt, Baird, & Hendrie, 2021; Springmann et al., 2018). These diets are defined by FAO as *"dietary patterns that promote all dimensions of individuals' health and well-being, have low pressure and environmental impact, are accessible, affordable, safe and equitable, and are culturally acceptable"* (FAO and WHO, 2019). At present, no existing dietary model is set to simultaneously measure all the sustainability principles identified by the FAO, especially environmental ones (Machado et al., 2023). Although quantifying the environmental impact of different types of foods and/or diets through tools such as, for example, Life Cycle Assessment (LCA) is not new in the literature (Aidoo, Abe-Inge, Kwofie, Baum, & Kubow, 2023; Benvenuti, De Santis, & Cacchione, 2021; Donati et al., 2016; Hallström, Carlsson-Kanyama, & Börjesson, 2015; Perignon et al., 2016; Poore & Nemecek, 2018; Tepper, Kissinger, Avital, & Shahar, 2022; Tucci et al., 2022; Yin et al., 2020), such tools do not measure how much such impact costs society.

* Corresponding author.
*E-mail address:* nicoletta.pellegrini@uniud.it (N. Pellegrini).
[1] These authors contributed equally to this work.

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A particularly useful tool for bridging this gap is True Cost Accounting (TCA), defined as *"a holistic and systemic approach to measure and value the environmental, social, health and economic costs and benefits generated by agrifood systems to facilitate improved decisions by policymakers, businesses, farmers, investors and consumers"* (FAO, 2023; Hendriks et al., 2021, 2023; Marangon, Bertossi, & Troiano, 2023; True Cost Initiative, 2022; von Braun & Hendriks, 2023). TCA is an analytical framework that, as LCA, allows for the quantification of environmental impacts associated with activities (or products) along the agri-food supply chain; to these impacts is then attributed a cost understood as *"the investment required to reduce emissions to a level that avoids negative impacts"* and *"how much it is worth to society today to avoid the damage that is expected in the future"* (True Cost Initiative, 2022). Thus, TCA translates negative impacts on the biosphere (e.g. greenhouse gasses emissions, water use, land use) into monetary terms, effectively helping the global community to better understand the "true cost" of the current agri-food system that it must bear (Hendriks et al., 2023; Marangon et al., 2023; von Braun & Hendriks, 2023). Moreover, it supports addressing the steps and practices along the supply chain that produce the greatest negative impacts, and finding new, more sustainable ways forward (Hendriks et al., 2023; Marangon et al., 2023; von Braun & Hendriks, 2023). TCA is a rather versatile tool and has already been applied in the literature for the general evaluation of an entire agri-food system (Hendriks et al., 2023; von Braun & Hendriks, 2023), a specific dietary pattern (Minotti et al., 2022), or foods (Michalke et al., 2023).

One area where the literature is still uncovered is using TCA for the evaluation of traditional foods and food preparations. Traditional food can be defined as *"a product frequently consumed or associated with specific celebrations and/or seasons, normally transmitted from one generation to the next, carefully made in a specific way according to gastronomic heritage, with little or no processing/manipulation, distinct and known for its sensory properties and associated with a certain local area, region or country"* (Guerrero et al., 2009). Traditional foods play a key role in achieving sustainability (FAO and WHO, 2019; Trichopoulou, 2012). From a social point of view, they are an expression of the historical, cultural and identity values of a specific place. From an environmental point of view, their preservation (or readaptation) over time can lead to the preservation of plant and animal biodiversity, as well as limited disturbance in ecosystems (Trichopoulou, 2012). Over the years, globalization has led to a progressive shift away from culture and traditions, causing imbalances also in the environmental and nutritional spheres (Popkin, Adair, & Ng, 2012). This has occurred in different parts of the world (Gabriel, Ninomiya, & Uneyama, 2018; Yin et al., 2020), including the Mediterranean area (Obeid, Gubbels, Jaalouk, Kremers, & Oenema, 2022), considered by many experts as the cradle of one of the most sustainable existing dietary patterns (Dernini et al., 2017). In this regard, this international recognition of the value of the Mediterranean Diet and the increasing demand for traditional and high-quality products by consumers (Antonelli & Viganò, 2018) have pushed European countries, particularly Mediterranean ones, to support the rediscovery, protection, and promotion of local and traditional foods. As an example, in Europe, a legal framework was designed to set distinctive schemes (named: protected designation of origin, protected geographical indication, and traditional speciality guaranteed) to help the consumer identify traditional and/or local food products through a simple logo. Given this complex framework, traditional foods must find their rightful place in a changing food system and prepare for the sustainable challenges that society will face in the future. This can be achieved by applying standardized approaches not only to preserve and enhance the production and quality of traditional foods (Antonelli & Viganò, 2018) but also to study their nutritional composition and the environmental impacts associated with their production. Although quantifying the environmental impacts of foods (Cerutti, Bruun, Donno, Beccaro, & Bounous, 2013), production methods (Bava et al., 2018) and cooked dishes (Calderón, Herrero, Laca, & Díaz, 2018) associated with a certain geographical region or tradition is a topic already addressed in the literature, there is currently no study that has applied the TCA approach.

The present research study aims to fill this gap and contribute to the development of knowledge on TCA by using this framework for the sustainability assessment of traditional dishes from the Italian region Friuli Venezia Giulia. In addition to this, a second objective is to perform a nutritional analysis of such dishes, contributing to the growth of the literature on the topic of traditional dishes in Italy (Costa, Vasilopoulou, Trichopoulou, & Finglas, 2010; Durazzo et al., 2017; Durazzo et al., 2019; Santangelo et al., 2022).

## 2. Materials and methods

A sample of traditional dishes from the Friuli Venezia Giulia region, north-eastern Italy, was selected from four popular recipe books (Molinari Pradelli, 2003; Sanguinetti, 2010; Stelvio, 2013; Valli, 2012) which collect recipes of different areas of the region, from the coast to the mountains. Dishes were selected based on popularity (i.e., presence in multiple recipe books, social imaginary of regional food).

### 2.1. Energy and nutrient calculation

To estimate the energy and nutrient composition of the selected dishes, we used ingredient list and ingredient weights to create a recipe based on standard procedures (Vásquez-Caicedo, Bell, & Hartmann, 2008). Undefined ingredient weights (e.g., a spoon, a glass, a pinch) and the weight of natural units (e.g., one egg, one tomato) were defined based on the Italian standard portions (SINU, 2014) or estimated.

The nutrient composition of each ingredient was entirely derived from the food composition database for epidemiological studies in Italy (Gnagnarella, Salvini, & Parpinel, 2022). When a direct match between one recipe ingredient and one database food item was not possible, the most similar one was selected. Yield factors (Bognár, 2002; USDA, 1975) were applied to consider the possible weight losses or gains due to food processing and cooking, based on the type of food and cooking method (Vásquez-Caicedo et al., 2008). Yield factors were rather applied at the recipe level; when not applicable because of the lack of specific data, yield factors were applied at the ingredient level. Portion sizes of cooked dishes were estimated based on the cookbook indication of the number of portions resulting from the total recipe.

Energy content was calculated from macronutrients, including fiber (Greenfield & Southgate, 2003), applying each nutrient-specific conversion factor (Gnagnarella et al., 2022; Greenfield & Southgate, 2003). Finally, checks were performed to control for possible errors and/or omissions: calculations were considered appropriate when the sum of water and macronutrients ranged between 95 and 105 g/100 g (Machackova et al., 2018).

### 2.2. Environmental impact calculation and TCA

To assess environmental sustainability, we applied the SU-EATABLE LIFE dataset (Petersson et al., 2021), which was the result of a revision, until January 2020, of literature data on carbon footprint (CF) and water footprint (WF). This dataset contains aggregated CF data for 323 food items and 85 food typologies and aggregated WF data for 320 food items and 72 food typologies per kg of food. We matched each ingredient with a food item or typology from the dataset, following the instructions given by the authors. The final CF and WF values of each traditional dish were then calculated summing the impacts of each ingredient for its weight, with the same procedure used for nutrient calculations, assuming a proportionality of CF and WF measures by weight.

TCA followed the procedure described and applied in the literature (Minotti et al., 2022; True Cost Initiative, 2022). The values of CF (expressed in kg $CO_2$ eq.) and WF (expressed in L $H_2O$) of each ingredient ($i$) were first multiplied by a specific monetisation factor (MF) to convert the different environmental units into monetary units and then added together, resulting in the total true cost (TC) per recipe:

$$TC_{dish} = \sum_{i=1}^{n} (CF_i \, x \, MF_{carbon}) + (WF_i \, x \, MF_{water})$$

$TC_{dish}$ = true cost of dish; n = number of ingredients of each recipe; $CF_i$ = carbon footprint of each ingredient *(i)* (kg $CO_2$ eq.); $WF_i$ = water footprint of each ingredient *(i)* (L $H_2O$); $MF_{carbon}$ = monetization factor for carbon emissions; $MF_{water}$ = monetization factor for water use.

The TC value was calculated per 100 g (€/100 g) and per portion (€/portion). The latter was calculated by multiplying the TC value (€/100 g) by the grams of the portion specified in the recipe book and dividing by 100 g. The MFs used for the procedure were taken from the current literature and are equal to 0.116 €/kg $CO_2$ eq. (True Price Foundation, 2023) and 0.163 €/kg $CO_2$ eq. (True Cost Initiative, 2022) for carbon emissions, 0.001 €/L for water use (Minotti et al., 2022).

The two carbon emission monetization factors used in this study are those reported by the two True Cost guidelines (True Cost Initiative, 2022; True Price Foundation, 2023). The choice of using two factors instead of one allowed for the creation of a confidence interval within which to place the part of the True Cost associated with carbon emissions.

## 3. Results

The 21 selected traditional dishes of the Friuli Venezia Giulia region

**Table 1**
Energy and nutrient composition of traditional dishes of the Friuli Venezia Giulia region expressed per 100 g and portion.

| Traditional dish | Portion | Energy | | Water | Total Prot. | Anim. Prot. | Veg. Prot. | Total fat | Anim. fat | Veg. fat | SFA | MUFA | PUFA | Av. Carb. | Sol. Carb. | Fiber |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | g | kJ | kcal | g | g | g | g | g | g | g | g | g | g | g | g | g |
| **First courses** | | | | | | | | | | | | | | | | |
| *Cjalzòns della Val di Gorto* | 100 | 1151 | 274 | 45.6 | 7.8 | 3.3 | 4.5 | 12.6 | 11.6 | 0.9 | 6.91 | 3.75 | 0.74 | 34.0 | 4.1 | 1.2 |
| | 293* | 3372 | 803 | 133.6 | 22.8 | 9.7 | 13.1 | 36.8 | 34.0 | 2.7 | 20.24 | 10.98 | 2.16 | 99.7 | 12.1 | 3.6 |
| *Gnocchi di prugne* | 100 | 672 | 159 | 61.4 | 3.9 | 0.4 | 3.5 | 2.6 | 2.3 | 0.3 | 1.37 | 0.71 | 0.22 | 30.8 | 6.3 | 2.1 |
| | 269* | 1809 | 427 | 165.2 | 10.5 | 1.1 | 9.4 | 7.0 | 6.3 | 0.7 | 3.67 | 1.92 | 0.59 | 82.8 | 16.9 | 5.8 |
| *Blecs (toppe)* | 100 | 990 | 236 | 56.8 | 6.2 | 2.8 | 3.4 | 11.3 | 10.8 | 0.5 | 6.15 | 3.21 | 0.69 | 28.8 | 0.5 | 1.0 |
| | 264* | 2611 | 622 | 149.8 | 16.4 | 7.4 | 9.0 | 29.7 | 28.4 | 1.3 | 16.22 | 8.47 | 1.83 | 75.9 | 1.4 | 2.6 |
| *Lasagne carniche (Blecs)* | 100 | 890 | 211 | 56.4 | 5.1 | 0.6 | 4.5 | 7.5 | 7.0 | 0.5 | 4.29 | 2.06 | 0.47 | 32.1 | 3.4 | 1.4 |
| | 327* | 2911 | 691 | 184.4 | 16.6 | 2.0 | 14.6 | 24.6 | 23.0 | 1.6 | 14.03 | 6.74 | 1.54 | 105.1 | 11.1 | 4.7 |
| *Strucolo con piselli* | 100 | 825 | 196 | 57.4 | 7.6 | 1.4 | 6.2 | 6.3 | 5.0 | 1.3 | 2.25 | 2.73 | 0.84 | 27.4 | 2.5 | 3.0 |
| | 299* | 2462 | 585 | 171.4 | 22.8 | 4.3 | 18.5 | 18.7 | 14.9 | 3.9 | 6.71 | 8.16 | 2.52 | 81.8 | 7.5 | 9.1 |
| **Main courses** | | | | | | | | | | | | | | | | |
| *Anitra (masuro) in umido* | 100 | 889 | 213 | 58.6 | 26.0 | 26.0 | Tr | 12.0 | 9.9 | 2.1 | 3.40 | 6.26 | 1.65 | 0.2 | 0.2 | 0.1 |
| | 221* | 1964 | 470 | 129.3 | 57.4 | 57.3 | 0.1 | 26.5 | 21.9 | 4.6 | 7.52 | 13.83 | 3.65 | 0.4 | 0.4 | 0.2 |
| *Baccalà alla triestina* | 100 | 811 | 194 | 61.4 | 21.5 | 20.8 | 0.8 | 9.6 | 9.5 | 0.1 | 5.20 | 2.71 | 0.65 | 5.4 | 0.7 | 0.3 |
| | 214* | 1738 | 415 | 131.5 | 46.1 | 44.5 | 1.6 | 20.7 | 20.4 | 0.3 | 11.15 | 5.80 | 1.39 | 11.6 | 1.6 | 0.6 |
| *Frico* | 100 | 1349 | 324 | 44.7 | 17.5 | 16.4 | 1.1 | 24.0 | 17.4 | 6.5 | 11.28 | 10.17 | 1.16 | 9.7 | 0.2 | 0.9 |
| | 139* | 1868 | 449 | 61.9 | 24.3 | 22.7 | 1.6 | 33.2 | 24.2 | 9.1 | 15.63 | 14.09 | 1.61 | 13.5 | 0.3 | 1.2 |
| *Musetto e brovada* | 100 | 769 | 185 | 69.4 | 9.7 | 8.7 | 0.9 | 14.3 | 13.5 | 0.8 | 4.61 | 6.69 | 2.47 | 3.7 | 3.7 | 2.3 |
| | 301* | 2320 | 559 | 209.2 | 29.1 | 26.4 | 2.8 | 43.1 | 40.8 | 2.3 | 13.91 | 20.19 | 7.44 | 11.0 | 11.0 | 6.8 |
| *Spezzatino di carne all'ungherese (goulash)* | 100 | 766 | 185 | 68.4 | 11.5 | 11.1 | 0.4 | 14.6 | 14.5 | 0.1 | 5.79 | 5.89 | 2.16 | 1.8 | 1.8 | 0.4 |
| | 185* | 1420 | 342 | 126.8 | 21.2 | 20.6 | 0.7 | 27.0 | 26.8 | 0.2 | 10.73 | 10.91 | 4.01 | 3.3 | 3.3 | 0.8 |
| *Trippa* | 100 | 833 | 200 | 64.3 | 14.7 | 14.5 | 0.2 | 15.1 | 15.1 | Tr | 5.15 | 6.16 | 2.73 | 1.3 | 1.3 | 0.4 |
| | 198* | 1646 | 396 | 127.1 | 29.1 | 28.7 | 0.4 | 29.8 | 29.8 | 0.1 | 10.18 | 12.17 | 5.39 | 2.5 | 2.5 | 0.7 |
| *Uccelli scampati* | 100 | 1028 | 247 | 55.5 | 22.9 | 22.9 | 0.1 | 17.0 | 17.0 | Tr | 5.91 | 7.66 | 2.54 | 0.4 | 0.4 | 0.1 |
| | 173* | 1780 | 427 | 96.1 | 39.7 | 39.6 | 0.1 | 29.5 | 29.5 | Tr | 10.23 | 13.26 | 4.40 | 0.7 | 0.7 | 0.1 |
| **Soups** | | | | | | | | | | | | | | | | |
| *Jota* | 100 | 736 | 147 | 74.5 | 4.4 | 1.8 | 2.6 | 8.9 | 8.5 | 0.4 | 3.48 | 3.23 | 1.73 | 12.3 | 3.0 | 1.8 |
| | 546* | 4017 | 962 | 486.6 | 28.7 | 11.7 | 17.0 | 58.0 | 55.4 | 2.6 | 22.75 | 21.12 | 11.33 | 80.6 | 19.6 | 11.9 |
| *Brodetto alla gradese* | 100 | 748 | 180 | 68.6 | 12.3 | 12.1 | 0.1 | 14.0 | 6.9 | 7.1 | 2.94 | 7.84 | 2.39 | 1.1 | 1.1 | 0.1 |
| | 227* | 1614 | 389 | 148.0 | 26.5 | 26.2 | 0.3 | 30.3 | 14.9 | 15.4 | 6.33 | 16.91 | 5.15 | 2.5 | 2.5 | 0.3 |
| *Sûf (Zuf)* | 100 | 703 | 167 | 63.8 | 4.8 | 1.7 | 3.1 | 4.7 | 4.1 | 0.6 | 2.47 | 1.32 | 0.43 | 27.5 | 3.0 | 0.9 |
| | 318* | 2239 | 530 | 203.1 | 15.4 | 5.6 | 9.9 | 14.9 | 13.0 | 2.0 | 7.88 | 4.22 | 1.38 | 87.5 | 9.6 | 3.0 |
| **Side dishes** | | | | | | | | | | | | | | | | |
| *Fagioli in umido* | 100 | 884 | 212 | 56.8 | 11.2 | 4.5 | 6.7 | 11.2 | 10.5 | 0.7 | 4.02 | 4.26 | 1.93 | 14.9 | 1.6 | 4.8 |
| | 209* | 1846 | 442 | 118.6 | 23.4 | 9.4 | 14.0 | 23.5 | 22.0 | 1.5 | 8.40 | 8.89 | 4.04 | 31.2 | 3.4 | 10.1 |
| *Patate in tecia* | 100 | 673 | 161 | 67.3 | 2.5 | Tr | 2.5 | 7.5 | 7.4 | 0.1 | 3.21 | 3.23 | 0.89 | 21.0 | 1.3 | 2.0 |
| | 167* | 1127 | 269 | 112.7 | 4.2 | Tr | 4.2 | 12.6 | 12.4 | 0.2 | 5.37 | 5.41 | 1.49 | 35.2 | 2.2 | 3.3 |
| **Desserts** | | | | | | | | | | | | | | | | |
| *Gubana* | 100 | 1667 | 397 | 19.1 | 8.9 | 1.8 | 7.0 | 17.6 | 5.7 | 11.9 | 4.05 | 5.15 | 6.12 | 52.7 | 34.9 | 2.5 |
| | 228* | 3794 | 903 | 43.5 | 20.3 | 4.1 | 15.9 | 40.1 | 13.0 | 27.1 | 9.23 | 11.71 | 13.93 | 119.9 | 79.3 | 5.7 |
| *Pinza* | 100 | 1672 | 394 | 8.1 | 9.7 | 0.9 | 8.6 | 6.1 | 5.6 | 0.5 | 3.22 | 1.66 | 0.60 | 79.0 | 19.7 | 2.1 |
| | 214* | 3584 | 845 | 17.3 | 20.7 | 1.9 | 18.3 | 13.1 | 11.9 | 1.2 | 6.91 | 3.55 | 1.29 | 169.4 | 42.2 | 4.5 |
| *Potiza di Gorizia* | 100 | 1832 | 437 | 15.6 | 9.4 | 1.0 | 8.0 | 21.8 | 8.0 | 13.9 | 6.44 | 4.49 | 7.92 | 52.6 | 16.1 | 2.7 |
| | 137* | 2514 | 600 | 21.5 | 13.0 | 1.4 | 10.9 | 30.0 | 10.9 | 19.0 | 8.83 | 6.17 | 10.87 | 72.2 | 22.1 | 3.7 |
| *Strucolo con uva* | 100 | 863 | 204 | 52.5 | 5.2 | 1.4 | 3.9 | 4.0 | 3.6 | 0.4 | 2.01 | 1.09 | 0.43 | 38.3 | 13.9 | 1.6 |
| | 154* | 1329 | 314 | 80.8 | 8.1 | 2.1 | 6.0 | 6.2 | 5.6 | 0.5 | 3.10 | 1.67 | 0.67 | 59.0 | 21.5 | 2.4 |

Abbreviations: Tr, traces; Prot., protein; Anim., animal; Veg., vegetable; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; Av. Carb., available carbohydrates; Sol. Carb., soluble carbohydrates. *weight of one portion, calculated based on the cookbook indication.

(Table 1) can be divided in first courses (*Cjalzòns della Val di Gorto*, *Gnocchi di prugne*, *Blecs*, *Lasagne carniche*, and *Strucolo con piselli*), soups (*Brodetto alla gradese*, *Jota*, and *Sûf*), main (second) courses (*Anitra in umido*, *Baccalà alla triestina*, *Frico*, *Spezzatino di carne all'ungherese*, *Musetto e brovada*, *Trippa*, and *Uccelli scampati*), side dishes (*Fagioli in umido*, and *Patate in tecia*), and desserts (*Gubana*, *Pinza*, *Potiza di Gorizia*, and *Strucolo con uva*). The full list of ingredients can be found in Supplementary Table 1, together with the quantity and the matching of each ingredient with the Italian Food Composition Database (Gnagnarella et al., 2022).

### 3.1. Energy and nutrient composition

Table 1 shows the energy and nutrient composition of the selected traditional dishes, which is extremely variable even among dishes of the same course category.

The first courses are cereal-based and salty, except for *Cjalzòns della Val di Gorto*, *Gnocchi di prugne*, and *Lasagne carniche* which present some sweet ingredients in it (sugar, plums, raisins). The coexistence of sweet and salty taste in a dish is typical in the region. Soluble carbohydrate content varies from 1.4 g/portion of *Blecs* to almost 17 g/portion of *Gnocchi*. The energy content of one portion of first course ranges between 427 kcal for about 270 g of cooked *Gnocchi* filled with plums, to nearly a double value (803 kcal) for 290 g of *Cjalzòns* which is a typical filled pasta with a butter sauce which also has the highest total fat content (36.8 g). Saturated fatty acids (SFA) are the most abundant fats in all first courses except for *Strucolo,* due to the ubiquitous presence of butter and/or cheese.

Regarding main courses, *Frico* is the only vegetarian dish (cheese, potatoes and olive oil) and the most energy-dense second course (324 kcal/ 100 g). One portion of *Frico* (about 140 g) contains 33.2 g of fats, half of which are SFA. *Baccalà alla triestina* is a fish-based second course. However, other than 370 mg/portion of docosahexaenoic acid (DHA), which is a typical fatty acid of fish-based dishes, it contains high SFA (11.15 g/portion) because it is made of dried cod and cream. The protein content of meat-based second courses varies between 57.4 g/portion in *Anitra in umido*, which is made of duck meat, to 21.2 g/portion for the beef-based *Spezzatino di carne all'ungherese*. *Musetto e brovada*, which is a very typical pairing of cooked pork sausage meat and slow-cooked turnips previously soaked in wine pomace, has the highest total fats (43.1 g/ portion), mainly represented by monounsaturated fatty acids (MUFA).

The soups of the region are very different from each other. *Brodetto alla gradese* is a mixed fish soup popular in the coastal area, *Jota* is a mixed soup with beans, vegetables, corn flour and pork products, and *Sûf* is a simple soup typically eaten at breakfast made with corn/wheat flour and milk. The latter is richer in carbohydrates (87.5 g/portion) compared to the other soups. *Brodetto alla gradese* has a good content of proteins (26.5 g/portion) and PUFA (5.15 g/portion), of which 510 mg/ portion are represented by eicosapentaenoic acid and 720 mg/portion by DHA. However, its composition may change depending on the type of fish used, which is not clearly defined in the cookbook being a dish made by fishermen with unsaleable and unsold fish leftovers. *Jota* is also a dish originally made from leftover foods and due to the diversity of its ingredients (beans, pork meat and fat, vegetables, corn flour, milk) and the small number of portions indicated in the cookbook (corresponding to more than 500 g of *Jota* per portion) may be considered a high-fat main course (962 kcal/portion of which 12 % protein, 54 % fats, 31 % carbohydrates, and 2 % fiber).

Side dishes are made of beans and salami (*Fagioli in umido*), or potatoes cooked with onions and pork fat (*Patate in tecia*). Even if it is traditionally considered a side dish, the *Fagioli in umido* could also be consumed as a second course due to its high content of energy (442 kcal/ portion) and proteins (23.4 g/portion). Moreover, it also contains 10.1 g/portion of fiber.

*Gubana*, *Pinza*, and *Potiza di Gorizia* are Easter desserts popular in different areas of the region made of leavened dough, plain (*Pinza*) or filled with dried fruit and mixed nuts (*Gubana*) or walnuts and chocolate (*Potiza di Gorizia*). Differences in the fillings are reflected in PUFA composition, which ranges between 1.29 g/portion of *Pinza* to 13.93 g/ portion of *Gubana*.

### 3.2. Environmental impacts and TCA

Table 2 shows the CF, WF and TC values per 100 g of each dish considered in the study, while Figure 1 shows what happens when comparing the TC/100 g with the amount of total proteins, classifying each dish according to the type of protein (vegetable or animal). Table 2 and Figure 1 clearly show that the three most impactful dishes have a high content of animal protein (mainly from beef, as shown in Supplementary Table 1), i.e. *Goulasch triestino* (CF = 1.436 kg $CO_2$ eq.; WF = 859.56 L $H_2O$), *Trippa* (CF = 2.363 kg $CO_2$ eq.; WF = 1063.511 L $H_2O$) and *Uccelli scampati* (CF = 2.758 kg $CO_2$ eq.; WF = 1685.371 L $H_2O$). Translating these data into monetary terms, the three dishes also are the only ones to have a total TC greater than € 1 per 100 g (€ 1.05–1.11 in the case of *Goulasch triestino*; € 1.34–1.45 in the case of *Trippa*) and € 2 per 100 g (€ 2.00–2.13 in the case of *Uccelli scampati*). It should be noted that also *Anitra in umido*, *Baccalà alla triestina* and *Frico* have a higher content of animal protein than vegetable protein. However, compared to the first three dishes, their TC/100 g is lower (€ 0.47–0.48 in the case of *Anitra in umido*; € 0.40–0.41 in the case of *Baccalà alla triestina*; € 0.47–0.50 in the case of *Frico*). Two other dishes whose environmental impacts are noteworthy are *Potiza di Gorizia* (CF = 0.179 kg $CO_2$ eq.; WF = 480.308 L $H_2O$) and *Gubana* (CF = 0.168 kg $CO_2$ eq.; WF = 396.591 L $H_2O$). Despite having a higher content of vegetable protein than animal protein, the environmental impacts shown in Table 2 are consistent and the TC/100 g is € 0.50–0.52 in the case of *Potiza di Gorizia* and € 0.42–0.43/100 g in the case of *Gubana*.

**Table 2**
Carbon footprint, water footprint and the true cost of traditional dishes of the Friuli Venezia Giulia region expressed per 100 g and ordered by Total TC.

| Traditional dish | CF (kg $CO_2$ eq./ 100 g) | TC CF (€/100 g) | WF (L $H_2O$/ 100 g) | TC WF (€/100 g) | Total TC (€/100 g) |
|---|---|---|---|---|---|
| *Patate in tecia* | 0.074 | 0.01 | 98.753 | 0.10 | 0.11 |
| *Strucolo con uva* | 0.105 | 0.01–0.02 | 115.413 | 0.11 | 0.12–0.13 |
| *Suf* | 0.126 | 0.01–0.02 | 126.432 | 0.13 | 0.14–0.15 |
| *Lasagne carniche (Blecs)* | 0.121 | 0.01–0.02 | 137.887 | 0.14 | 0.15–0.16 |
| *Strucolo con piselli* | 0.113 | 0.01–0.02 | 150.462 | 0.15 | 0.16–0.17 |
| *Insalata di fagioli* | 0.05 | 0.01 | 162.123 | 0.16 | 0.17 |
| *Blecs (toppe)* | 0.189 | 0.02–0.03 | 172.999 | 0.17 | 0.19–0.20 |
| *Gnocchi di prugne* | 0.072 | 0.01 | 187.424 | 0.19 | 0.20 |
| *Pinza* | 0.123 | 0.01–0.02 | 214.446 | 0.21 | 0.21–0.22 |
| *Jota* | 0.163 | 0.02–0.03 | 205.363 | 0.21 | 0.23–0.24 |
| *Cjalzòns della Val di Gorto* | 0.241 | 0.03–0.04 | 205.82 | 0.21 | 0.24–0.25 |
| *Musetto e brovada* | 0.281 | 0.03–0.05 | 304.84 | 0.30 | 0.33–0.35 |
| *Brodetto alla gradese* | 0.41 | 0.05–0.07 | 338.981 | 0.34 | 0.39–0.41 |
| *Baccalà alla triestina* | 0.331 | 0.04–0.05 | 356.558 | 0.36 | 0.40–0.41 |
| *Gubana* | 0.168 | 0.02–0.03 | 396.591 | 0.40 | 0.42–0.43 |
| *Anitra (masuro) in umido* | 0.271 | 0.03–0.04 | 441.494 | 0.44 | 0.47–0.48 |
| *Frico* | 0.554 | 0.06–0.09 | 408.184 | 0.41 | 0.47–0.50 |
| *Potiza di Gorizia* | 0.179 | 0.02–0.03 | 480.308 | 0.48 | 0.50–0.52 |
| *Spezzatino di carne all'ungherese (goulash)* | 1.436 | 0.17–0.23 | 859.56 | 0.88 | 1.05–1.11 |
| *Trippa* | 2.363 | 0.27–0.39 | 1063.511 | 1.06 | 1.33–1.45 |
| *Uccelli scampati* | 2.758 | 0.32–0.45 | 1685.371 | 1.69 | 2.01–2.14 |

Abbreviations: CF, carbon footprint; WF, water footprint; TC, true cost.

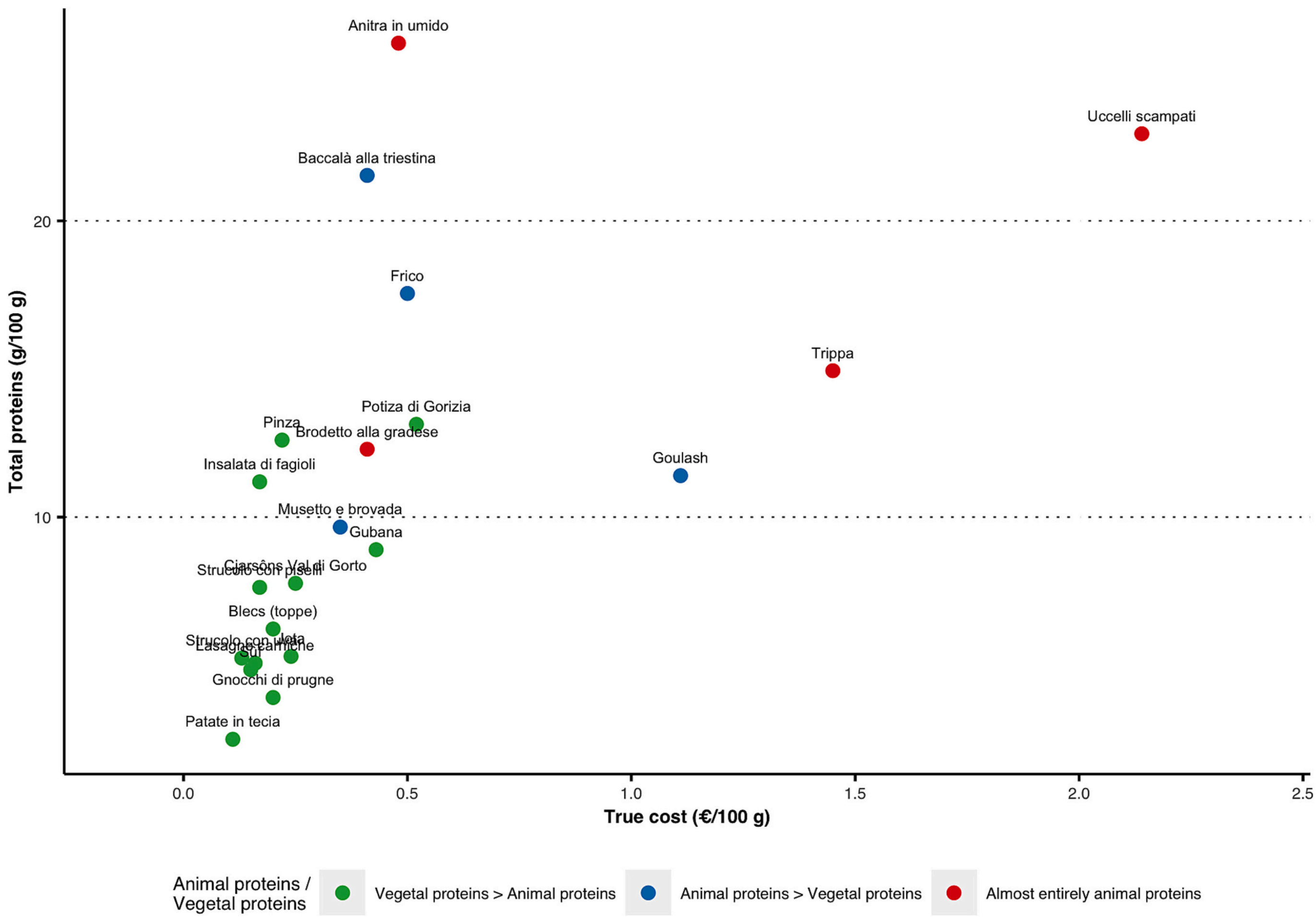


**Fig. 1.** Relation between true cost and protein content (total, animal/vegetal) of the dishes, expressed per 100 g.

**Table 3**
True cost (TC), energy, protein content and the ratio between animal and vegetable proteins of traditional dishes of the Friuli Venezia Giulia region expressed per 100 g and portion.

| Traditional dish | TC (€/100 g) | TC (€/portion) | Total prot. (g/100 g) | Total prot. (g/portion) | Anim./veg. protein index | |
|---|---|---|---|---|---|---|
| *Patate in tecia* | 0.11 | 0.18 | 2.50 | 4.20 | 0.00 | Veg. prot ≥ anim. Prot. |
| *Strucolo con uva* | 0.13 | 0.29 | 5.24 | 8.07 | 0.40 | Veg. prot ≥ anim. Prot. |
| *Sûf (Zuf)* | 0.15 | 0.46 | 4.85 | 15.43 | 0.60 | Veg. prot ≥ anim. Prot. |
| *Lasagne carniche (Blecs)* | 0.16 | 0.51 | 5.07 | 16.59 | 0.10 | Veg. prot ≥ anim. Prot. |
| *Strucolo con piselli* | 0.17 | 0.50 | 7.63 | 22.77 | 0.2 | Veg. prot ≥ anim. Prot. |
| *Insalata di fagioli* | 0.17 | 0.35 | 11.19 | 23.39 | 0.70 | Veg. prot ≥ anim. Prot. |
| *Blecs (toppe)* | 0.20 | 0.54 | 6.22 | 16.41 | 0.80 | Veg. prot ≥ anim. Prot. |
| *Gnocchi di prugne* | 0.20 | 0.54 | 3.91 | 10.52 | 0.1 | Veg. prot ≥ anim. Prot. |
| *Pinza* | 0.22 | 0.50 | 12.60 | 20.72 | 0.1 | Veg. prot ≥ anim. Prot. |
| *Jota* | 0.24 | 1.26 | 5.30 | 28.70 | 0.70 | Veg. prot ≥ anim. Prot. |
| *Cjalzòns della Val di Gorto* | 0.25 | 0.72 | 7.76 | 22.75 | 1.00 | Veg. prot ≥ anim. Prot. |
| *Musetto e brovada* | 0.35 | 1.06 | 9.66 | 29.15 | 9.5 | Anim. prot. > veg. Prot. |
| *Brodetto alla gradese* | 0.41 | 0.87 | 12.29 | 26.52 | 85.30 | Almost entirely anim. Prot. |
| *Baccalà alla triestina* | 0.41 | 0.88 | 21.54 | 46.14 | 27.5 | Anim. prot. > veg. Prot. |
| *Gubana* | 0.43 | 0.96 | 8.90 | 20.27 | 0.3 | Veg. prot ≥ anim. Prot. |
| *Anitra (masuro) in umido* | 0.48 | 1.07 | 26.00 | 57.42 | 530.7 | Almost entirely anim. Prot. |
| *Frico* | 0.5 | 0.69 | 17.55 | 24.30 | 14.4 | Anim. prot. > veg. Prot. |
| *Potiza di Gorizia* | 0.52 | 0.70 | 13.13 | 12.97 | 0.1 | Veg. prot ≥ anim. Prot. |
| *Spezzatino di carne all'ungherese (goulash)* | 1.11 | 2.06 | 11.40 | 21.20 | 29.9 | Anim. prot. > veg. Prot. |
| *Trippa* | 1.45 | 2.86 | 14.94 | 29.09 | 73.4 | Almost entirely anim. Prot. |
| *Uccelli scampati* | 2.14 | 3.69 | 22.94 | 39.72 | 287.9 | Almost entirely anim. Prot. |

Abbreviations: TC, true cost; Prot., proteins; Anim., animal; Veg., vegetal. Notes: the TC value (€/100 g) reported in the table corresponds to the upper limit of the range of the total TC (€/100 g) reported in Table 2. The anim./veg. protein index was calculated by dividing the animal protein content (g/100 g) by the vegetable protein content (g/100 g).

Among the analysed dishes (Table 2), some favor the use of vegetables, cereals, pulses and a variable amount of milk and/or dairy products, such as *Patate in tecia* (CF = 0.074 kg $CO_2$ eq.; WF = 98.753 L $H_2O$), *Strucolo con uva* (CF = 0.105 kg $CO_2$ eq.; WF = 115.413 L $H_2O$), *Sûf* (CF = 0.126 kg $CO_2$ eq.; WF = 126.432 L $H_2O$), *Lasagne carniche* (CF = 0.121 kg $CO_2$ eq.; WF = 137.887 L $H_2O$), *Strucolo con piselli* (CF = 0.113 kg $CO_2$ eq.; WF = 150.462 L $H_2O$) and *Fagioli in umido* (CF = 0.05 kg $CO_2$ eq.; WF = 162.123 L $H_2O$). Such dishes have a much lower environmental impact than the more animal-based ones. Expressing these data in monetary terms, the total TC of these dishes (characterized by a higher content of vegetable protein than animal protein) does not exceed € 0.20 per 100 g (Table 2, Figure 1).

When the results are analysed per portion, rather than 100 g, the TC increase is not uniform (Table 3 and Figure 2). In general, a more pronounced increase in TC per portion was noted in the cereal-based foods (*Jota*, *Sûf*, *Lasagne carniche* and *Strucolo con piselli*) and more modestly in the animal-based foods (*Frico*, *Uccelli scampati* and *Goulash triestino*). However, there were exceptions, such as *Musetto e brovada* (a meat and vegetable-containing dish for which there is a threefold increase in TC) and *Potiza di Gorizia* (a dessert for which the TC only slightly increases). The greatest increase (more than five times) is shown for *Jota*, a dish with a higher content of vegetable protein than animal protein but a high content of animal fats. When related to 100 g, its TC is intermediate (€ 0.24/100 g), but if related to one portion (546 g), the TC is the fourth highest (€ 1.26/portion), lower only than that of *Goulash triestino* (€ 2.06/portion), *Trippa* (€ 2.86/portion) and *Uccelli scampati* (€ 3.69/portion), which are all beef-based dishes. The opposite case is *Frico*, which is a product with a high animal protein content due to the presence of cheese: the TC/100 g is the fifth highest value (€ 0.5/100 g), but when related to a portion (136 g), its value drops sharply to the middle of the ranking (€ 0.69/portion).

## 4. Discussion

To our knowledge, the present study is the first attempt to translate the environmental impact of traditional dishes into monetary values using the TCA methodology. The worth of the TCA is precisely that of synthesizing in a single economic indicator (in our case, €/100 g and €/portion) all the environmental indicators (e.g., greenhouse gas emissions, water use, land use) for which, otherwise, separate units would be needed. In other words, the TCA wants to act as a new lens through which to observe what one usually does not see when producing and purchasing a food product. Another important merit of the present study is to have combined nutritional and environmental/economic aspects in the study of traditional dishes. In this regard, the results are in line with the current literature, which reports animal-based dishes (particularly those with a beef base) as a major source of environmental impacts (Clark et al., 2022; Ernstoff et al., 2019; Poore & Nemecek, 2018; Scarborough et al., 2014; Takacs, Stegemann, Kalea, & Borrion, 2022; Volanti et al., 2022) and of increased hidden costs to society (Lucas, Guo, & Guillén-Gosálbez, 2023). This is true when referring to the quantity of 100 g, but in reality, much depends on the type of ingredients and the portion consumed. Indeed, our results highlight that it is not so much the amount of animal proteins that causes an increase in TC, but rather its source (e.g., type of animal) and processing method. As an example, *Baccalà alla triestina* and *Anatra in umido*, which contain a

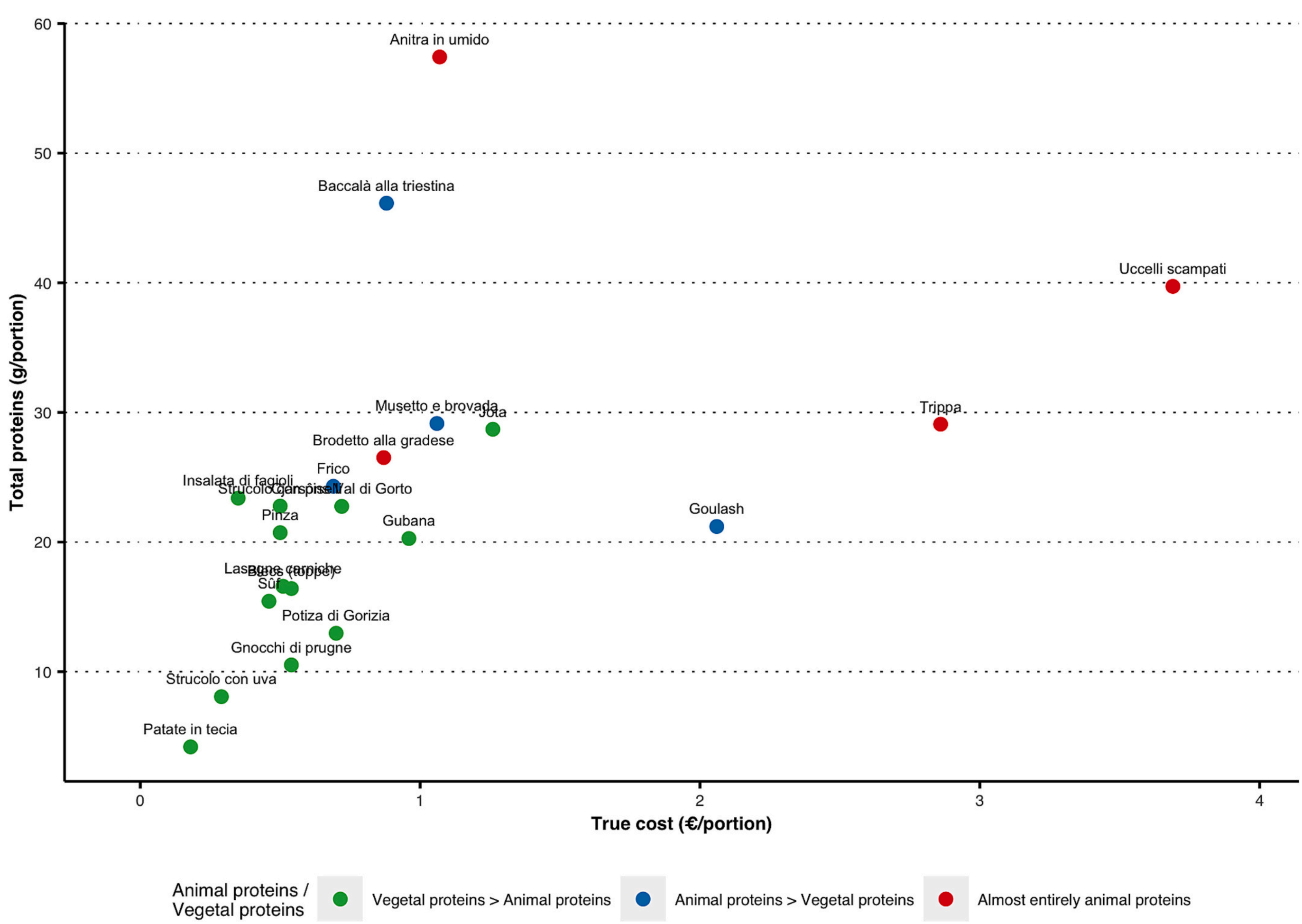


**Fig. 2.** Relation between true cost and protein content (total, animal/vegetal) of the dishes, expressed per portion, as indicated in the cookbooks.

higher amount of animal proteins per 100 g than *Trippa* (for both dishes) and *Uccelli scampati* (only for *Anitra in umido*), show a lower TC due to the absence of beef. Moreover, we find that it is not always the case that a dish made of mainly plant ingredients has a lower TC than a dish mainly made of animal-origin ones. This is the case, for example, of *Potiza di Gorizia* and *Gubana*. These desserts, despite a moderate CF value, have a high WF value due to the presence of walnuts, almonds and butter, making their TC/100 g the fourth and seventh highest, respectively, and even higher than dishes with a high meat content such as *Anitra in umido* (in the case of *Potiza di Gorizia*) and *Brodetto alla gradese* (in the case of *Gubana*). Indeed, nuts raise the WF value of the dish, while butter increases the two environmental indicators simultaneously due to an increase in animal lipids rather than animal proteins.

When the analysis of TCA is performed based on dish portions, a strong increase in TC is found in certain preparations (especially those with a predominantly vegetable base) because of the very large suggested portion sizes from the cookbooks. The lack of standardized portion sizes when analyzing traditional dishes has forced us to use portions suggested by the cookbooks. As an example, while some portion sizes can be confidently associated with medium-sized portions of similar Italian dishes (e.g., *Gnocchi di prugne,* 270 g vs. *Gnocchi* with butter, 240 g (Turconi & Roggi, 2007), others cannot. This is the case of *Jota*, which portion size calculated based on the cookbook (almost 550 g) is similar to the large portion of the Italian vegetable and rice soup (525 g) (Turconi & Roggi, 2007). This large portion, which also has a high energy content, can explain the high TC value. On the other hand, *Frico* portion size resulting from the cookbook is relatively small (139 g cooked weight) and cannot be matched to similar Italian dishes. Standard portions for its ingredients, separately, are 200 g for potatoes and 50–100 g for cheese, depending on the ripening stage of cheese (SINU, 2014). As a result, this lack of defined portion sizes of traditional dishes might have altered the results expressed by portion. Although the increase in TC following an increase in portion size is rather obvious, highlighting it allows us to emphasize the importance of the definition of suitable portion sizes for the adoption of sustainable diets. The definition of standard portions for traditional dishes, based on national recommendations (SINU, 2014), should be encouraged to regulate recipe book portion number indications.

It is noteworthy to mention that the current analysis presents some limitations. First of all, ours is an exploratory study. Even if the selected dishes were chosen based on popularity in the whole region and specific areas, the sample analysed should not be assumed to be comprehensive of traditional dishes consumed in the Friuli Venezia Giulia region. Indeed, we referred to four cookbooks (Molinari Pradelli, 2003; Sanguinetti, 2010; Stelvio, 2013; Valli, 2012) and alternative versions of the same dish were not included in the analysis. Another important limitation is the use of an international environmental database (Petersson et al., 2021) that cannot yet accurately differentiate foods of local origin from imported foods in terms of CF and WF and does not report other environmental indicators (e.g., land use). Consequently, in the application of the TCA methodology, we could only calculate the monetary value ascribable to CF and WF, obtaining preliminary data which only represent a fragment of the TC of foods. Moreover, we assumed the proportionality of the environmental impacts of the ingredients by weight. That is a necessary and frequently assumed assumption although it may not be correct. Therefore, our study intends to lay the fundaments to further studies designed to consider actual environmental indexes of food preparations of local origin through the implementation of a full LCA analysis. Besides the limitations, this study may have multiple implications. The knowledge of both the nutritional composition of foods and their environmental/economic impact may be useful to the three main actors in the agri-food system, namely the producers of such dishes (e.g., restaurants, canteens, food industry), consumers (who consume traditional dishes or prepare them at home) and policy-makers (who devise strategies for the development of agri-food systems that favors sustainability while maintaining tradition). Specifically, data that emerged from the present study may be used to consciously incorporate traditional dishes in sustainable menus, diets, or dietary guidelines (e.g., local food pyramids), modulating portion sizes, frequency of consumption, or even reformulating the recipes to improve nutritional and environmental aspects while preserving traditional values. Such a systemic approach, with interventions at the micro (i.e., individual), *meso* (i.e., corporate or commercial) and macro (i.e., institutional) levels, can lead to the adoption of healthy diets, the reduction of carbon emissions and may be the key to the right shift towards sustainability (Hoek, Malekpour, Raven, Court, & Byrne, 2021; Mbow et al., 2019). For example, several studies testify an increasing sensitivity of consumers to environmental issues and how this influences their food choices (e.g., Bimbo, 2023). Therefore, demonstrating that environmental impacts have been considered by producers in food preparation, or quantifying the environmental impact of a certain type of diet (Scarborough et al., 2014) can be an important lever to amplify this change.

In conclusion, the current study displays valuable data on the nutritional and environmental aspects of a sample of traditional dishes from the northeastern part of Italy whose gastronomical tradition is also influenced by the neighboring (Slovenian and Austrian) cuisine. Moreover, the analysis provides preliminary data on the TC of foods based on their environmental impacts, highlighting the great potential of the TCA methodology. Future perspectives of the present study are i) to expand the analysis including more traditional food preparations, both from the Friuli Venezia Giulia and other Italian regions, ii) to differentiate the environmental analysis based on the usage or not of ingredients of local origin, iii) to estimate the TC of foods applying factors associated with other environmental indexes, and finally iv) to combine nutritional and TC data to create a new comprehensive indicator including all aspects of food/diet sustainability.

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**Ethics statement**

The study does not involve the use of human subjects or human data.

**CRediT authorship contribution statement**

**Federica Fiori:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Alberto Bertossi:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Stefania Troiano:** Writing – review & editing, Supervision, Project administration, Methodology. **Maria Parpinel:** Writing – review & editing, Supervision, Methodology. **Francesco Marangon:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Nicoletta Pellegrini:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jff.2024.106587.

**Data availability**

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

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