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Towards a sustainable diet combining economic, environmental and nutritional objectives

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ABSTRACT

Foods consumed and dietary patterns are strong determinants of health status. Diet and nutrition have a key role in health promotion and maintenance during the entire lifetime, but what we choose to eat and drink greatly affects the environmental impact on ecosystems as well as monetary resources. Some studies suggest that a healthy diet with a low environmental impact is not necessarily more expensive. This paper aims to identify a healthy, greener and cheaper diet based on current consumption patterns. Dietary information was collected from 104 young adults in the last year of high school in Parma (Italy). Diet was monitored with 7-day dietary records. Subsequently, food items were decoded to obtain nutritional, economic and environmental impact data. An optimization tool based on mathematical programming (Multi-Objective Linear Programming) was used to identify sustainable diet. Three different 7-day diets were identified, based on nutrition recommendations for the healthy Italian adult population, characterized by different targets and optimizing different impacts: first the diet at the lowest cost (Minimum Cost Diet – MCD), then the Environmentally Sustainable Diet (ESD) obtained by minimizing the three environmental indicators (CO_2e emissions, H_2O consumption and amount of land to regenerate the resources – m^2). Finally, the Sustainable Diet (SD) was identified by integrating environmental and economic sustainability objectives. Lastly, suggestions and recommendations for communication campaigns and other interventions to achieve sustainable diet are suggested.

1. Introduction

Foods consumed and dietary patterns are strong determinants of health status during our entire lifetime, and what we choose to eat and drink also has environmental impact on ecosystems and affects monetary resources (Duchin, 2005; WHO, 2008). The agricultural and food sector is responsible for more than 25% of all greenhouse gas (GHGs) emissions, contributing to fresh and marine water pollution, and using about a half of ice-free land area on Earth as cropland and pasture (Tilman & Clark, 2014). Animal origin food production causes greater environmental impacts than fruit and vegetable production, and most plant-based foods can have protective effects against the major chronic diseases (De Marco, Velardi, Camporeale, Screpanti, & Vitale, 2014). Moreover, some studies suggest that a healthy diet with a low environmental impact is not necessarily more expensive (Barilla Center for Food and Nutrition, 2011; Conforti & D'Amicis, 2000; Germani et al., 2014). Population growth, agriculture intensification, lifestyle changes, poverty, and food security are also part of this picture leading to the necessity to re-define food systems and dietary patterns from environmental and health perspectives (Hallström, Carlsson-Kanyama, & Börjesson, 2015; Johnston, Fanzo, & Cogill, 2014).

It is generally acknowledged that what a person chooses to eat makes a difference from an environmental perspective (van Dooren, Marinussen, Blonk, Aiking, & Vellinga, 2014; Vieux, Darmon, Touazi, & Soler, 2012). For instance, Marlow and colleagues (2009) have estimated that a non-vegetarian diet requires 2.9 times more water, 2.5 times more primary energy, 13 times

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more fertilizer, and 1.4 times more pesticides than the vegetarian diet. It has been estimated that Mediterranean, pescetarian and vegetarian diets may reduce by 30%, 45% and 55% respectively per capita emissions from food production, as compared to projected 2050 income-dependent diet (Tilman & Clark, 2014). These diets might therefore be considered more sustainable than others. One of the first formalizations of the concept of sustainable diet was introduced in the seminal work by Gussow and Clancy (1986), who looked at foods from the nutritional point of view and also considering their impact on natural resources. More recently, the FAO provided a new definition which takes into account the role of dietary patterns on sustainable development and the elimination of poverty and food insecurity: "Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" (FAO, 2010, p. 7).

The positive impacts of sustainable diets are related to public health (e.g., reduced diet-related chronic disease, etc.), environmental sustainability (e.g., mitigation of water and land use, reduction of GHG emissions, etc.), economic sustainability (e.g., employment and trade opportunities, etc.), social inequalities (e.g., closing gaps in health, incomes and food affordability in developed and developing countries, etc.), and other possible benefits (e.g., psychological and physical well-being, animal welfare, cultural and social diversity, etc.) (Johnston et al., 2014). The multidimensional character of sustainable diets is given by factors and effects that are closely interconnected and interdependent, so that modifying one or more components of a diet might have different and unintended effects across these categories. For instance, although reducing beef consumption might improve environmental quality and public health, it could negatively affect the economic stability of beef producers and related food systems. Public authorities aiming at stimulating sustainable consumption need to consider these links carefully.

Affordability, income distribution and costs related to food products are further important determinants influencing food choices. The sudden price increases of food commodities on world markets after 2008 led to increased concern over the ability of the world food economy to adequately feed billions of people (FAO, 2011). At the same time, the globalization of the food system has contributed to the spread of cheaper foods high in energy but low in important nutrients in developed and developing countries (Johnston et al., 2014). This means that unless sustainable options become more affordable, people will continue to disregard environmental considerations when making food purchases. Moreover, it was suggested that inequities exist in the affordability of the health and sustainable food basket and the typical basket at the household level, with the most disadvantaged neighbourhoods and lowest income households spending proportionately more on sustainable food (Barosh, Friel, Engelhardt, & Chan, 2014). Other studies have demonstrated that total expenditure on a healthy (Conforti & D'Amicis, 2000) and environmental sustainable diet (Barilla Center for Food and Nutrition, 2011) would in fact be lower than the actual current expenditure.

Health, affordability and environment are the three key components of food consumption which need to be balanced for there to be a sustainable diet in line with health recommendations. Literature suggests that these three dimensions of the sustainable diet might be represented as and accommodated in optimization problems. One potentially useful class of operational research tools is mathematical programming (Dantzig, 1948; Paris, 1991; Stigler, 1945). Mathematical programming, linear programming in particular, has long been used to identify adequately healthy, environmentally friendly and affordable human diets. The Nobel Prize winning economist George Stigler formulated one of the first linear programming problems on the minimum cost of diet for the American population in 1945. Subsequently, various researchers tried to optimize human diet using optimization techniques. Briend, Darmon, Ferguson, and Erhardt (2003) suggested the application of linear programming to support paediatricians in identifying complementary foods to provide children of 6–24 months of age with additional energy and nutrients. Macdiarmid et al. (2012) developed a linear programming model able to identify a diet which would be environmentally resource saving, acceptable and economically reasonable for the United Kingdom population. Their study shows the potential of mathematical programming as a tool to make the use of food resources for global warming mitigation efficient without increasing the food expenditure for consumers. These authors impose a series of constraints, beyond the macro and micro-nutrient constraints, to reach a realistic solution for the different scenarios through lower and upper weight food limits. The issue of realistic palatable and varied diet was also tackled by Wilson et al. (2013) through linear programming, where the objective was to suggest for New Zealand consumers a healthy, cheap and environmentally sustainable food basket. They indicated that results from an optimization model can be used to design planning policy instruments to promote the consumption of healthy and environmental sustainable foods. Communication campaigns, labelling and economic instruments such as taxation can be used to orient the public to a more aware and sustainable diet.

This study aims to identify a healthy, greener and cheaper diet based on current consumption patterns. We considered the dietary patterns of a sample of 104 young adults attending high school, and assessed their nutritional, environmental and economic impacts. This target group was selected in the light of current concerns about low dietary quality of young adults and consequent possible dietary deficiencies (Turconi et al., 2008). In this framework, we performed an optimization analysis using a linear programming model to produce nutritionally correct 7-day diets that minimize the environmental impact (ecological sustainability) and the cost paid by consumers (economic sustainability), considering at the same time palatability and viability constraints. The resulting dietary scenarios should be in line with recommendations for a healthy diet (SINU, 2012). The results will be useful to inform food policy makers about the health, economic and environmental impact of the current dietary patterns of young Italians, and to suggest possible interventions to achieve a more sustainable diet.

2. Material and methods

2.1. Data collection

Dietary information was collected from students attending eight different final year classes in high schools in Parma (Italy). The schools were selected in order to include participants with different socio-economic backgrounds. One-hundred twenty participants were recruited but 16 were eliminated because of data missing from the dietary record. The final sample included 104 young adults (38 male; 66 female), age 18–20 years, BMI 21.8 ± 3.3 Kg/m^2 (mean ± standard deviation). Their diet was monitored with 7-day weighed dietary records (Dall'Asta et al., 2012). Participants were asked to weigh all food and drinks consumed and to use standard household measures (e.g. table spoon, tea spoon, cup) to estimate the amount where weighing was not possible. A food diary database with a list of 544 food items was created. Food items included in dietary records were used to create a nutritional database, linked to the food code of the European Institute of Oncology (EIO) database (Gnagnarella, Salvini, & Parpinel, 2008). The following nutritional values were selected from the database: energy, proteins, total