

# Water Global Health Benefit: the Water Footprint of the Dietary Patterns and the Acceptability of a 100% Plant-Based Diet

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**Abstract:** Water is exhaustible, but fundamental in a perspective for the global health. Food choices seem to play a relevant impact on human water consumption. We assessed the water footprint of widespread dietary patterns and we used a mix-method approach. We administered an adapted version of a 17-item questionnaire to a sample of young subjects, aimed to assess the level of acceptability of the diet that showed the lowest water consumption. The 100% plant-based was the winner diet, but its acceptability was weak. Our findings support current evidences promoting the adherence to a low-or-non-animal-based diet which favors human and environmental health.

**Keywords:** food literacy; environmental health literacy; Mediterranean diet; hand washing

## 1. Introduction

Water is one of the most precious natural resources because it is essential for life, so that it is fundamental to warrant its use to everyone in terms of human rights and living in human dignity [1-3]. Moreover, water on Earth is not endless but limited and exhaustible, and current data show a worrying growing water scarcity. Already today, in some areas of the Planet, about eight hundred thousand people lack access to sufficient and safe water and about three billion people are not benefitting an adequate sanitation [4]. Some experts also observed that there is a significant decline in the availability of fresh water, and it results in harmful effects on human health [5].

In this pandemic era, water availability, as well as water consumption, are put in crisis to the fact that the one of the most effective interventions in curbing the spread of Covid-19 is an ongoing sanitation and cleaning hands [6-7]. For this reason, now more than ever water scarcity is a critical condition to forefront.

The current water demand is very high and will grow steadily in the future. It has been estimated that 70% of fresh water is absorbed by agriculture, while 22% is for industry, and the remaining 8% is for domestic purposes [2].

In addition, Willett et al. [8] stated that global food production is among the largest drivers of global environmental change and strongly contributes to freshwater use. The same experts [8] have defined the characteristics of the so-called *planetary diet*, that is a plant-based diet and adequate in preserving human and environmental health. On the basis of the relationship among environmental and human health [8], we conducted the present research with two specific aims:

- (1.) To assess the water footprint of five widespread dietary patterns (Western diet [9], Mediterranean diet [10], flexitarian diet [8], diet for athletes [11], and 100% plant-based diet [12]);
- (2.) To assess the level of acceptability of the winner diet, that proved to exert the lowest water consumption, by involving a convenience sample of young adults who voluntarily filled in an online questionnaire.

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## 2. Material and Methods

We based on specific definitions of the concepts of water footprint and acceptability, that are described as following. Water footprint of a food product was intended as the total volume of fresh water that is used directly or indirectly to produce it; and it is estimated by considering water consumption and pollution in all the steps of the production chain [13]. Regarding the term acceptability, it has been conceptualized as the level of preference of dietary pattern referred by people and could represent an indicator of individuals' propensity to adopt specific dietary habits [14]. Two phases were considered in our research: the first one foresaw the calculation of the water footprint of the five dietary patterns described (Phase 1); the second in assessing the level of acceptability of the winner diet (Phase 2).

### 2.1. Water footprint of the five selected dietary patterns, Phase 1

Firstly, we planned a daily hypothetical food plan for each dietary pattern (Western diet, Mediterranean diet, flexitarian diet, diet for athletes, and 100% plant-based diet) which are shown in the Appendix A (Please see Table A1). Calculations of nutrients were based on the food databank of the Italian National Food Research Institute (ex-INRAN, nowadays renamed CREA) [15] and we also referred to the latest recommended nutrient intake levels for the Italian population (LARN) and classified by the Italian Society of Human Nutrition (SINU) [16].

Secondly, we calculated the water footprint of the five dietary plans considering both the water footprint calculator ( $\text{m}^3$  per year) [17] and a manual calculation (liters per capita per day) on the basis of tables with a complete list of water consumption of foods and beverages retrieved by literature [4]. In both methodological approaches, the water consumption was estimated by adding the values of water footprint of each food item in the dietary plan.

### 2.2. Level of acceptability, Phase 2

A survey was conducted to evaluate the level of acceptability of the winner diet and  $N = 126$  young adults (mean age, 26 years old; females, 62.7%) participated in the study. Data were collected using a self-administered questionnaire, that included a general section for socio-demographic characteristics and the 17-item questionnaire, named Food Acceptability Questionnaire (FAQ) [14], previously translated and adapted to the Italian context. Participants voluntarily agreed to join the study and filled in the questionnaire administered online. All the adopted procedures were in accordance with the ethical standards of the Declaration of Helsinki and data were collected anonymously.

## 3. Results and Discussion

Regarding the water footprint of the five dietary patterns, the results obtained are summarized in Table 1 and Table 2.

**Table 1.** Software calculation of the water footprint.

Dietary Patterns	Water Footprint ( $\text{m}^3$ per year)
100% plant-based diet	354
flexitarian diet	486
Mediterranean diet	640
Western diet	1.094
diet for athletes	1.126

**Table 2.** Manual calculation of water footprint.

Dietary Patterns	Water Footprint (liters per capita per day)
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I.	100% plant-based diet	2.089
II.	flexitarian diet	2.335
III.	Mediterranean diet	2.400
IV.	diet for athletes	3.241
V.	Western diet	3.780

The 100% plant-based diet is the winner diet, since it has the lowest water consumption in both calculations made. Additionally, data collected by means of the 17-item questionnaire suggested it showed an intermediate level of acceptability (mean score, 3.86).

We noted that diet for athletes had the highest water consumption when the calculation referred to the first methodology, while this is true for Western diet when the calculations was hand-made on the basis of tabulated values [4] (Please see Table 1 and Table 2).

Considering our results, we argued that it is possible to identify two different dietary clusters regarding water consumption: a low water consumption group, that includes the 100% plant-based diet, the Mediterranean diet, and the flexitarian diet (mean water footprint, 493 m<sup>3</sup> per year *or* water consumption, 2.275 liters per capita per day); and a second high consumption water group that includes Western diet and diet for athletes (mean water footprint, 1.110 m<sup>3</sup> per year *or* water consumption, 3.510 liters per capita per day).

#### 4. Conclusions

To reach a high level of adherence to a healthy diet whilst achieving a low environmental impact is one of the Sustainable Development Goals (SDGs) of the UN 2030 Agenda whose explicit aim is to improve people's quality of life while protecting our Planet's resources [18].

According to our results, the adherence to a 100% plant-based diet could favor the reduction of water consumption (in terms of 740 m<sup>3</sup> per year of water *or* 1.691 liters per capita per day). We argued that the adoption of a dietary pattern with a high amount of foods obtained from plants could contribute in limiting the environmental impact and better protecting, at the same time, human health. However, a strong limitation in promoting this dietary model is represented by the intermediate level of people's acceptability: this is a critical aspect that should be considered in any attempt to promote dietary patterns close to vegan.

Future interventions should therefore be focused in increasing people's awareness and responsibility on the water impact of our food choices and how to reduce, by means of the most appropriate ones, water consumption.

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**Appendix A - Table A1.** Daily hypothetical food plan planned for the five dietary patterns considered.

Hypothetical plan * for Western diet	Hypothetical plan * for Mediterranean diet	Hypothetical plan * for flexitarian diet	Hypothetical plan * for diet for athletes	Hypothetical plan * for 100% plant-based diet
<b>Breakfast</b> whole milk, 150 ml sugar breakfast cereal, 40 g biscuits, 3-4 (optional choice: a slice of bread with scrambled eggs, 2)	<b>Breakfast</b> coffee espresso, 30 ml low fat milk, 150 ml a slice of whole grain bread + marmalade, 25 g fresh fruit, 1 (optional choices: a slice of homemade fruit tart <i>or</i> whole-grain cereals for breakfast, 40 g)	<b>Breakfast</b> low fat milk <i>or</i> vegetable milk (such as almond or soy milk), 150 ml whole-grain cereals for breakfast, 40 g fresh fruit, 1 (optional choices: a slice of homemade fruit tart <i>or</i> biscuits, 3-4)	<b>Breakfast</b> low fat milk, 200 ml a slice of whole grain bread + marmalade, 25 g fresh fruit, 1 (optional choice: oatmeal, 50 g + one banana)	<b>Breakfast</b> vegetable milk added with calcium and vitamin D (such as almond or soy milk), 150 ml chia seeds, 10 g vegan biscuits, 3-4 <i>or</i> oat flakes, 40 g fresh fruit, 1
<b>Mid-morning Snack</b> a slice of white bread + butter, 25 g + fruit jam, 25 g	<b>Mid-morning Snack</b> low fat yogurt (without added sugar), 125 ml linoleum seeds, 1 teaspoon	<b>Mid-morning Snack</b> low fat yogurt (without added sugar), 125 ml walnuts, 30 g	<b>Mid-morning Snack</b> Greek yogurt (without added sugar), 150 ml (optional choice: a slice of bread with hazelnut cocoa cream, 20 g)	<b>Mid-morning Snack</b> soy yogurt (without added sugar), 125 ml walnuts, 30 g
<b>Lunch</b> bread, 50 g potatoes, 2 tomato sauce, 20 g seed oil, 10 ml fruit salad (a fresh fruit + vegetable, 1)	<b>Lunch</b> whole-grain cereals (such as spelt, rice, <i>or</i> whole-grain spaghetti), 100 g vegetables (raw or cooked), 200 g extra virgin olive oil, 10 ml walnuts <i>or</i> almonds, 30 g fresh fruit, 1	<b>Lunch</b> whole-grain cereals (such as spelt, rice, <i>or</i> whole-grain spaghetti), 100 g nutritional yeast, 1 teaspoon vegetables (raw or cooked), 200 g extra virgin olive oil, 10 ml fresh fruit, 1	<b>Lunch</b> whole-grain spaghetti ( <i>or</i> spelt, rice, <i>or</i> other whole-grain cereals), 90 g vegetables (raw or cooked), 200 g extra virgin olive oil, 10 ml fruit salad with a fresh fruit + oat flakes, 30 g	<b>Lunch</b> whole-grain cereals (such as spelt, rice, <i>or</i> quinoa), 100 g nutritional yeast, 1 teaspoon vegetables (raw or cooked), 200 g extra virgin olive oil, 10 ml fresh fruit, 1
<b>Mid-afternoon Snack</b> fruit juice, 200 ml sweet snack, 30 g	<b>Mid-afternoon Snack</b> a slice of whole grain bread + extra virgin olive oil, 5 ml + fresh tomato, 1	<b>Mid-afternoon Snack</b> a slice of whole grain bread + extra virgin olive oil, 5 ml + fresh tomato, 1	<b>Mid-afternoon Snack</b> a slice of whole grain bread + Parmesan, 30 ml <i>or</i> dry-cured ham, 40 g	<b>Mid-afternoon Snack</b> a slice of whole grain bread with sesame cream, 20 g <i>or</i> avocado, 60 g <i>or</i> extra virgin olive oil, 10 ml <i>or</i> dark chocolate, 30 g
<b>Dinner</b> spaghetti, 100 g butter, 25 g second course <sup>o</sup> such as cured meat, 40 g	<b>Dinner</b> second course <sup>I</sup> (legumes, <i>or</i> fish, <i>or</i> white meat, <i>or</i> eggs, <i>or</i> occasionally red <i>or</i> cured meat) three slices of whole grain bread	<b>Dinner</b> second course <sup>II</sup> (legumes, <i>or</i> tofu <i>or</i> tempeh, <i>or</i> cheese (cream <i>or</i> mature), <i>or</i> fish, <i>or</i> eggs, <i>or</i> occasionally meat)	<b>Dinner</b> second course <sup>III</sup> (legumes, <i>or</i> fish, <i>or</i> white meat, <i>or</i> eggs, <i>or</i> occasionally red meat <i>or</i> cured meat)	<b>Dinner</b> second course <sup>IV</sup> (legumes, <i>or</i> tofu <i>or</i> tempeh, <i>or</i> seitan) three slices of whole grain bread

1 coke	vegetables (raw or cooked), 200 g extra virgin olive oil, 10 ml fresh fruit, 1	three slices of whole grain bread vegetables (raw or cooked), 200 g extra virgin olive oil, 10 ml fresh fruit, 1	three slices of whole grain bread vegetables (raw or cooked), 200 g extra virgin olive oil, 10 ml fresh fruit, 1	vegetables (raw or cooked), 200 g extra virgin olive oil, 10 ml fresh fruit, 1
<b>Macronutrient and energetical contents:</b> energy (E), kcal: 2.459 proteins (P), g: 97 fats (F), g: 105 carbohydrates (C), g: 303	<b>Macronutrient and energetical contents:</b> energy (E), kcal: 2.184 proteins (P), g: 71 fats (F), g: 81 carbohydrates (C), g: 314	<b>Macronutrient and energetical contents:</b> energy (E), kcal: 2.216 proteins (P), g: 70 fats (F), g: 83 carbohydrates (C), g: 317	<b>Macronutrient and energetical contents:</b> energy (E), kcal: 2.613 proteins (P), g: 116 fats (F), g: 78 carbohydrates (C), g: 386	<b>Macronutrient and energetical contents:</b> energy (E), kcal: 2.200 proteins (P), g: 71 fats (F), g: 83 carbohydrates (C), g: 314

\* The five daily food plans for each dietary pattern were planned considering an ideal subject (aged between 30 and 59; mean weigh, 69 kg; estimated caloric expenditure, 2.200 kcal) who has not specific nutritional requirements owing to pathological or physiological conditions.

The frequencies considered for the second course differed among the five dietary patterns: **legumes**, 50-60 g (raw) or 150-180 g (cooked) – frequency considered was twice a week or more<sup>I,III</sup>, three times/week<sup>II</sup>, or four times/week<sup>IV</sup>; **fish**, 120-150 g – frequency considered was twice a week or more<sup>I,III</sup>, twice a month<sup>II</sup>; **white meat**, 100-150 g – frequency considered was once/twice a week<sup>I,III</sup>, or once/twice a month<sup>II</sup>; **eggs**, 2 or 100 g – frequency considered was once a week or less<sup>I,II,III</sup>; **red meat**, 100 g – frequency considered was once a week or less<sup>I,II,III</sup>; **cured meat**, 70 g – frequency considered was once per two weeks or less<sup>I,II,III</sup>; **cheese**, 100 g (cream cheese) or 50 g (matured) – frequency considered was once/twice a week<sup>II</sup>; **tofu or tempeh**, 100 g – frequency considered was once/twice a week<sup>II,IV</sup>; **seitan**, 100 g – frequency considered is once a week<sup>II,IV</sup>. Frequencies estimated for the second course of the Western diet were: **white meat**, 100 g – more than twice a week; **eggs**, 2 or 100 g – once a week; **red meat**, 100 g – more than once a week; **cured meat**, 70 g – more than once a week; **cheese**, 100 g (cream cheese) or 50 g (matured) – more than twice a week.

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