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ARTICLE IN PRESS

Improving food value chain through sustainability scores

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ABSTRACT

Customers are getting more interested in the quality and the environmental impact of food. Even when producers provide detailed information on the food supply chain, consumers feel overwhelmed by the amount of information to process. A questionnaire delivered to 1,000+ respondents in Italy revealed that customers look for quick information on their sustainability while grocery shopping. However, 23% of respondents don't have time to read labels. As a result, we propose a platform capable of facilitating customers' choices for high quality food. This includes a decision-making algorithm which takes into consideration all of the information provided by producers, delivering an immediate rating of the food based on its environmental and social impact.

Keywords: Food; sustainability; innovation.

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INTRODUCTION

Food has always played a crucial role in human society. From the hunters-gatherers who first populated the Earth more than ten thousand years ago, through the first farmers appeared around two thousand years later, until the global citizens of the nowadays industrialized world; every stage of humankind evolution has a social structure strongly interdependent on the Food Value Chain (FVC) of that age.

In the globalized world we live in today, FVC has become complex. Indeed, it currently conceals dozens of deeply rooted problems, from the unsustainable exploitation of the planet's resources to the waste of products and goods. In terms of sustainability, nowadays, FVC is responsible for one third of the global CO_2 production (FAO, 2019) and it is degrading the biodiversity, the soils and water bodies (Westhoek, 2016). Moreover, with the forecasted increase in world population from 7.2bn to 9.6bn by 2050 (Cohen, 2013), our soils will be asked to give us as much food as we have consumed in the last 500 years.

In parallel, customers' interest in making sustainable choices has considerably grown in recent years (Gelski, 2020). Consumers see their purchasing decisions as a form of activism. The experts refer to 'voting with their dollars' when describing the phenomenon of customers supporting producers whose behaviour is in line with their personal belief (Perret, 2020). However, consumers caring about food sustainability can still rely only on food labels and certifications. Indeed, they fail in comprehensively considering each of the aspects of food sustainability. As a matter of fact, transportation usually accounts for no more than 6% of the total environmental impact of food (Ritchie and Roses, 2020). Indeed, the unsustainability of the food supply chain derives from a variety of reasons; from industrialisation and globalisation of food processing, to shift of the consumption patterns towards animal protein-based diets, to modern lifestyles that favour heavily processed food (Reisch et al., 2017). Still, local food producers are usually considered as more sustainable, regardless of the conditions in which food is grown, harvested or processed.

This situation leads to misleading and incomplete information which leaves the customers confused and disoriented (Carrothers, 2020). Moreover, certified organic products typically cost to the final customer about 47% more than uncertified ones (Marks, 2015).

THEORETICAL BACKGROUND

Unsustainability of FVC

Sustainability is generally hard to define, since it has several meanings, depending on the context. Following European Commission definition, sustainability implies the use of resources at rates that do not exceed the capacity of the Earth to replace them. (European Commission, 2016). For a sustainable FVC, lots of different issues have

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to be taken into account, such as: security, health, safety, affordability, quality and, at the same time, environment, biodiversity, water and soil quality. (European Commission, 2016). Moreover, sustainability can be interpreted in relation to ethical issues; a product cannot be referred to as sustainable, if its production process included the violation of any human right. Environmental sustainability and the FVC are strictly related. Indeed, food production is responsible for one-quarter of the world's greenhouse gas emissions due to livestock and fisheries, crop production, land usage and supply chains (transport, packaging, retail) (Ritchie, 2020). Moreover, FVC is negatively impacting our planet in terms of reduced biodiversity, harmed soils and water, and fragmented habitats (Marks, 2015).

Certifications

A variety of certifications is nowadays in place to offer the customers a guarantee of buying sustainable products. For example, to protect the origins and the processes that make the unique characteristics of specific foods linked to their geographical origin, EU provided a 'geographical indication' (GI) certification (European Commission, 2012), which ensures to the customers all the mentioned above key characteristics. On the other hand, sustainability in ethical terms is certified since 2015 in Italy through the "Ethical Certification of agricultural workforce" (CSQA, 2015). It ensures that no illegal workers have been involved and exploited during the agricultural harvesting of the specific food on which the certification is applied.

Among all of the certifications, the organic or "bio" certification is one of the most common. For agricultural products and livestock, "bio" means that the item has been grown/raised following the rules of the EU Regulation on Organic Farming. For processed foods, "bio" guarantees that at least 95% of the ingredients of agricultural products comes from organic farming (European Community, 2008). However, this certification has two main drawbacks, one for the customers and one for the producers. First, it is directly sponsored by the farmers themselves (European Community, 2007); for many farmers, the cost is not tenable. Therefore, this results in cutting out of the certification most of the smaller farmers**.** On the other hand, certified organic products typically cost the final customer about 47% more than the uncertified ones (Marks, 2015).

Sustainability for customers

In recent years, customers' interest in making sustainable choices has grown considerably. A study released by Gelsk (2020) shows an increase of 23% of consumers in the United States who prioritizes sustainable food choices compared to previous years. Baudry (2017) proposed an analysis of the motivation behind over 22,000 people's food choices. On average, it resulted that the main drive is taste, followed by health and absence of contaminants. Moreover, FoodInsight (2018) conducted an online survey of 1,009 Americans showing that for 6 out of 10 consumers it was important that the purchased food had been produced in a sustainable way, with an increasing trend compared to 2017. However, customers have few means that help them make sustainable choices. As shown in the study by Carrothers (2020), which took 1,003 U.S household customers from ages 21-69 as sample, consumers are actually interested in sustainable food but most of them do not know how to define or identify it. Indeed, among the 66% of customers which are interested in sustainable food choices, half of them do not know how to obtain more information. The necessary data to assess a complete analysis are complex, confusing and overwhelming for the average customer who can rely only on food certifications. Unfortunately, certifications do not consider every aspect of food sustainability in a comprehensive way. Moreover, they are so expensive that small producers cannot afford them. On the other hand, the higher price of certified food products apparently neglects the access to sustainable and quality food to a significant number of customers.

METHOD AND DATA

This section describes in detail the stages of our innovation journey and the innovation methodologies adopted to produce a solution capable of improving the food value chain. In particular, three main phases have been carried out through this process: a research phase, an ideation phase and an evaluation phase.

To approach the problem, at the very first stage we built a general understanding of it by studying the state of the art of the food value chain and the actual methodologies that are commonly used to achieve food traceability. We also interviewed several key stakeholders, in order to have a wider and practical overview of the problem and to clarify the market needs. In the second phase, we explored innovative ideas to solve the problem and we then prototyped them in the third phase. Initially, we prototyped an innovative system capable of organizing the weekly food shopping of a family unit, by taking into consideration the quality of food, the caloric intake of the family unit and the price of food to be purchased. To validate the market-solution fit, we decided to create a questionnaire to reach as many stakeholders as possible. This survey was built on a Google form and the link was distributed on social media like LinkedIn, Facebook and Whatsapp through different channels. The survey has been conducted in Italian language in order to reach an overview of Italian people's habits. The questionnaire received 1322 responses. We organized the questions according to the characteristics of the audience, dividing it into *people who only do the grocery shopping*, *people who only cook*, and *people who do both*. We also tracked the ages by dividing them into the following age groups: 0-20, 21-35, 36-50, 51-65, 65+

years old. While designing the questionnaire, we aimed at asking targeted questions to validate our hypotheses on people's food habits and to better understand the main factors influencing their choices. We asked the audience to rate from 0 to 5 how much it is habitual in food choices. Only to the portion of the audience who does the grocery shopping, we then asked to choose among five different factors that influence the most their choices when purchasing food. The five factors were: Vegan/Vegetarian, Bio (which stands for organic), Km 0 (which stands for local), Made in Italy and economic savings. Finally, we asked the public if it was interested in a system able to organize the shopping on the basis of the habitually consumed meals during the week, in order to automatically deliver habitudinal food choices to the consumers.

RESULTS

Among the people who answered our survey, 42.7% are in the 21-35 age group, 20.3% in the 36-50 and 26% in 51-65, showing a vast variety of consumers. The region with the highest rate in responses is Lombardia with 35.3%, followed by Puglia (22.8%) and Piemonte (9.5%). This proves that the audience ranges from north to south of Italy.

As a first important insight, the questionnaire revealed that more than 50% of people are recurrent in their food choices (Fig. 1). Furthermore, among the people who do the grocery shopping, for the 48.9% of them the main factor guiding choices while shopping is saving money, while for 61.3% of them is purchasing made in Italy products as a guarantor of quality (Fig. 2). This result shows how many interviewed consumers don't rely on or cannot afford to trust certifications when purchasing food, because only 25.8% selected the Bio label.

Regarding the question about scheduling repeatable purchases in order to get the food periodically delivered, in a preference range from 0 to 5, where 0 indicates absolute indifference to the system and 5 the absolute interest in using it, 23.1% of the audience indicated a vote of 5 and 31.2% a vote equal to 4, for a total of more than 50% of people interested in relying on this system. With these results, we validated our hypotheses about people's food choices which are habitual and made taking into account sustainability criteria.

Another factor to consider is the lack of time in the interviewed consumers: 24.3% states that they don't have time to read the labels. Starting from these results, we continued to develop our system, illustrated in the following section.

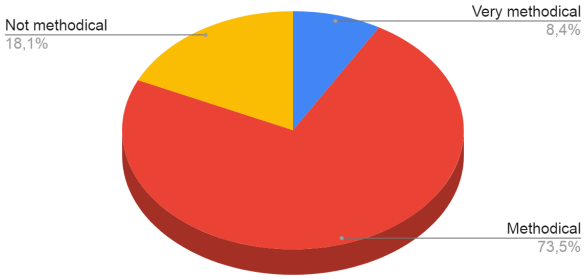

Fig. 1. Questionnaire results about the percentage of people who are methodical when buying food.

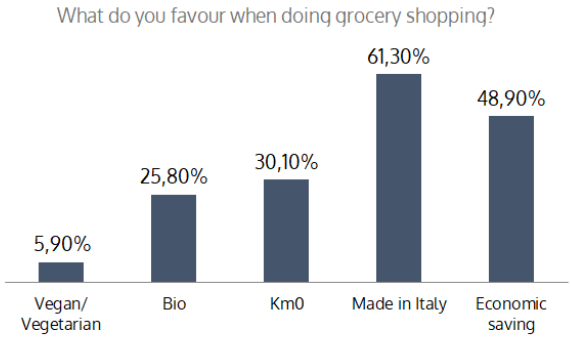

Fig. 2. Questionnaire results about the principal people's food choice

repEAT

As the questionnaire revealed, the average consumer is methodical in choosing what to eat during the week. Moreover, he is interested in purchasing sustainable food but he has neither the time nor the desire to analyze the data of each product before purchasing it. Therefore, we propose repEAT, an innovative solution to meet these needs. repEAT is a marketplace that collects, for each category of food, only highly traced - and not necessarily certified - products and suggests to the customer a comprehensive rating of them. Relying on a robust algorithm which takes into account 8 major parameters, it gives to each product three scores accounting for environmental sustainability, quality and social fairness. The scores give a comprehensive awareness of the food to the consumers, by using a friendly interface that allows to get more detailed data on customer requests. Moreover, after selecting the products on the platform, the customer is able to plan a continuous reordering of the chosen products, in order to make them periodically delivered to him. In this way, the platform is able to provide to the consumer the highest sustainable food products without having the customer to be overwhelmed with all the necessary information.

In the early stages, repEAT assesses the food sustainability of the small producers' products by

processing the data that small farmers can easily collect on their fields. The following paragraph goes deeper into the details of the algorithm and the data used to produce the scores.

Algorithm

The main goal of the algorithm is to collect and process the data of the raw agricultural products, in order to allow the customer to make a sustainable choice by providing three different scores for each of them. The developed algorithm is able to select, account and categorize the most significant parameters related to the raw agricultural products. The information is gathered by the farmer and provided to the platform to be proven true. The 8 parameters used as indicators to judge the quality of each food and its sustainability level are the following:

1. **Pesticides and fertilizers usage**: types and quantities of pesticides or fertilizers used in the soil. Farmers have to declare what they use on their fields: if some illegal types are included or if the quantity is over the maximum level accounted, the factor will be zero;
2. **Chemicals in the soil**: controls the presence of forbidden chemicals like heavy metals, checked by periodic chemical analysis;
3. **Origin of the products**: the closer the product to the end consumer, the lower the factor;
4. **Harvesting date**: gives an indication of the freshness of the final product. The closer the harvesting date to the actual date, the higher the parameter;
5. **Workforce**: checks if the workers have a regular contract, according to the law. If unregistered personnel are working in the fields, the factor will be zero. For this parameter, we considered equally relevant the information whether the producer holds the "Ethical Certification of agricultural workforce" recognition;
6. **Overall CO_2 emission**: including both transportation and machines utilized for the field. The lower the emissions, the higher the score;
7. **Water usage**: parameter that controls the water used to obtain the final product;
8. **Plastic usage**: accounts for plastic used both during production and transportation. The lower the amount, the higher the score.

The formulas used to calculate the parameters are presented in the Appendix. The different parameters are categorised in groups according to the three categories. For every parameter, a weighting function is defined following the guidelines of the rating criteria shown in Fig. 3. We considered the accuracy of the localization data, the emissions produced during the transportation and the harvesting of the products, the type and quantities of fertilizers and pesticides used, the quantity of water (liters) exploited to obtain the final products, the sustainability of the workforce certification, the amount of plastic or biodegradable plastic used and the time passed from harvesting time to the time when products are available to be delivered. Each individual contribution is taken into consideration along with the others and a rating is thus provided for each product on the marketplace. All these parameters are processed to obtain a final sustainability and quality score from 0 to 5 for every raw product present in the marketplace. In this way, the user can purchase the highest quality products in a very practical and simple way, without having to consider the available information which remains anyway accessible on the website for any further consultations.
It will be repEAT's duty to control that all the parameters provided by the farmers are correct. This will happen with periodic checks and tests on the field. The farmers will have to provide all the information required to be registered as resellers on the platform.

The system is designed to provide advantages both to customers and producers. Customers can easily make sustainable and high-quality food choices, while, at the same time, the small producers which are able to provide the necessary information can get the access to a digital platform in which they can promote their products and get their quality recognized, with no need of a label certification.

Index	Category	Rating Criteria
Fertilizers and pesticide	Quality	Types and quantities
Chemicals in soil	Quality	Presence of dangerous components in the soil
Harvesting time	Quality	Time passed from harvesting time
Sustainability of workforce	Social	Certification of sustainability of the workforce
Geographical origin	Environmental	Localization accuracy
CO2	Environmental	Emissions while transporting and harvesting
Water usage	Environmental	Quantity (liters) used to obtain the products
Plastic usage	Environmental	Amount of (biodegradable) plastic used

Fig. 3. Parameters used by the algorithm to classify products along with the rating criteria.

DISCUSSION AND CONCLUSIONS

Nowadays, FVC has revealed to be extremely unsustainable while impoverishing soil, groundwater and biodiversity. Consumers are proven to make methodical choices when they do grocery shopping and they are keen in looking for local, low-cost and organic products. A customer interested in sustainable food choices can rely on certifications which fail in taking into consideration every aspect of food sustainability. Moreover, consumers feel confused and overwhelmed in front of the amount of information they would have to analyze to make sustainable food choices. To meet these needs, in this paper we presented repEAT which is an innovative platform that exploits an innovative algorithm to rate products according to sustainability criteria. In this way, it facilitates customers' choices, by also planning periodical reorders.

The limitation of this work is the lack of availability in information regarding some algorithm parameters, e.g. the water usage, the pesticides and the overall CO_2

emissions. In fact, it is very difficult nowadays to find precise and reliable sources on fields that are not digitized. The advent of new technologies, such as the Internet of Things in fields, will pave the way for reliable information sources.

Future works

As a future work, we would be able to conduct essential validations by testing the repEAT algorithm in IdeaSquare environment. Indeed, thanks to the available computational power, it will be possible to calculate, for example, the amount of resources required to perform the calculations and the speed at which the score is computed. Given the need to provide users with real-time answers for a better user experience, the results of these experiments will enable the project to move forward.

Moreover, in a long-term prospective, the repEAT project has the additional purpose to digitize the farms, giving small producers selling on the marketplace access to new technologies for smart field management and food traceability. By doing so, we aim at continuously increasing the amount of considered criteria that will be valued on the platform on the basis of the real-time data coming from the fields.

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APPENDIX: QUESTIONNAIRE

List of questions presented in the conducted survey:

- Age
- Region of origin
- How many people does your household consist of?
- Are you habitudinary in food choices?
- Do you follow any diet?
- When you don't cook, what's the main reason?
- In your grocery shopping, which of the following factors are you influenced by? (Vegan/Vegetarian, Bio (Organic), km0 (local), Made in Italy, economical saving, nutritional indicators, others)
- How much time are you willing to spend to read labels? (none, 30 sec, 1 min+)
- In 10 years, how would you imagine grocery shopping to be?
- Would you use an app that, given a "weekly menu" would guide you doing your online grocery shopping in the supermarkets close to your home, buying only what is necessary and spending as little as possible?

APPENDIX: FORMULAS

Formulas for each parameter in the algorithm:

1. Pesticides and fertilizers usage:
$$F = \frac{Value - Min}{Max - Mix}$$
Where Max= 587[1] Min=0
2. Chemicals in the soil:
$C = 1$when one of the chemicals[2] in the list is above the minimum threshold, otherwise $C = 0$
3. Origin of the products:
O= 1-$\frac{Distance_{min} - Distance_i}{Distance_{min} - Distance_{max}}$
4. Harvesting date:
$$H = \frac{Today - Harvesting\ date}{Duration\ -\ Harvesting\ date}$$
5. Workforce:
$W = 1$when the certification is provided, otherwise $W = 0$
6. Overall CO_2 emission:
$CO_2 = \frac{Min\ distance - distance}{Min\ distance - Max\ distance} + CO_{2\ machines}$[3]
7. Water usage:
$$H_2O = 1 - \frac{Value - min}{max - min}$$
8. Plastic usage:
$P = 1$when plastic is not used for packaging, otherwise $P = 0$

[1] Calculated as the maximum number of pesticides

[2] (Gallini, 2000)

[3] This value is calculated based on approximation based on the information of the types of agricultural machinery used by the producer.