AGRICULTURAL UNIVERSITY OF ATHENS
DEPARTMENT OF FOOD SCIENCE & HUMAN NUTRITION
LABORATORY OF FOOD CHEMISTRY & ANALYSIS

MSc FOOD, NUTRITION & HEALTH
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Master Thesis

Alternative sources of protein: Expansion of the Hellenic Branded Food Composition Database HelTH with plant-based imitation products on the Greek market and the assessment of their nutritional quality

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Εναλλακτικές φυτικές πηγές πρωτεΐνης: Επέκταση της βάσης δεδομένων συσκευασμένων τροφίμων HelTH με υποκατάστατα τροφίμων φυτικής προέλευσης, η διερεύνηση τους στην Ελληνική αγορά και η αξιολόγηση της διατροφικής τους αξίας

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Abstract

Background

Plant-based imitations are new innovative food products designed to mimic the taste, texture, and appearance of animal-based products. They are typically made from ingredients like soy, wheat, or pea protein. Examples include imitations burgers, cheese, or sausages. While consumers are gradually choosing plant-based meat and dairy replacements, the nutritional quality and capability of these foods to serve as adequate substitutes is still under discussion and more research is needed to understand the nutritional quality but also the long-term health effects of plant-based analogs. Food composition databases (FCDBs) are tools that provide detailed information on the nutritional information of foods. They are used for various purposes related to nutrition, including determining population's nutritional status, researching diet-disease links and food industry processes such as nutritional labeling or food reformulation. The Greek Branded Food Composition Database (HelTH), is an example of a branded food composition database that includes data on 4002 products, since 2020.

Aim of the study

The purpose of this study is to update and expand HelTH's data, mapping the currently available meat and dairy imitations in Greece. The expansion is conducted by describing these meat and dairy products in terms of their content, including ingredients, nutrition or environmental claims, quality indicators, and their nutritional composition, both collectively and according to the alternative protein source that is the primary component of each product. Thus, the main aim is to compare these products' nutritional profiles between the different categories that result but also to those of their counterparts that are based on animal products. As part of a comparison of their nutritional composition with that of their counterparts, the food profiling system known as Nutri-Score is utilized to enrich the differences between the two in a way that is both straightforward and visually presented. The research also includes the development of a supplementary questionnaire- not the current study's top

priority-but its purpose is to record the attitudes and impressions of Greek consumers to plant-based imitation products.

Methods

The data collection process for this study is a crucial aspect of the research methodology. The information derived from each individual product package is used to gather detailed information on the food products being studied. The food data is organized and categorized using the Langual and EuroFIR food description and classification system. The information is recorded in Excel spreadsheets, which allows for easy organization and management of the data. To provide additional information and increase the validity of the study, new describing factors were included as part of the expansion procedure. These factors are chosen based on their relevance to the protein source and their ability to provide a more comprehensive understanding of the data. The Nutri-Score nutrient profiling system, macronutrient composition, nutrition claims, and package quality characteristics are all evaluated for all products. The Nutri-Score system is a widely recognized tool for assessing the nutritional quality of food products, and the examination of macronutrient composition, nutrition claims, and package quality characteristics provides a more holistic understanding of the products. Finally, the statistical analysis is conducted using the software IBM SPSS Statistics®, for comparisons and distributions assessment.

Results

Their primary component, nutritional composition and promotion as a healthy, nutrient-dense food were detailed, and their total nutritional quality was rated using the Nutri-Score algorithm. There were a total of 421 plant-based imitations tested, the majority of which were made of wheat or wheat blends (83.5% for meat imitations) and grain (19.8%) or vegetable oil (17.5%) for dairy imitations. All meat ones were high in protein and fiber, although only yogurts claimed to be high in protein (80.9%). Compared to their animal-based equivalents, the total fat and saturated fat content of imitation sausages, milk, and yogurt was lower. All dairy substitutes contained less protein than animal-based dairy.to their counterparts but this is not the case with dairy imitations , where especially, in accordance with the Nutri-Score system, plant-based cheeses were graded D–E as opposed to A–C for animal-based cheeses.

Conclusion

Plant-based imitations include frequently nutrition claims on their package. Wheat and soy-based formulations are suitable sources of protein, whereas

vegetable oil-based formulations contain no protein. Substituting specific food groups with plant-based alternatives may not support an equivalent or superior diet compared to their animal-based counterparts. This is a challenge for both the academic community and the industry sector, which should explore new sources or revise the use of existing ones by reformulating the matrix of plant-based substitutes to make them more nutritional, environmentally friendly, and fully equivalent to their counterparts.

Scientific area: Food Science and Nutrition

Keywords: Alternative Protein Sources, meat imitations, dairy imitations, substitutes, plant-based diet, vegan, nutritional composition, Branded Food Composition Database, HelTH, processed food, food labeling, Front of Pack Labelling Systems, declaration, food reformulation

Περίληψη

Εισαγωγή

Τα φυτικής προέλευσης προϊόντα απομίμησης είναι νέα καινοτόμα προϊόντα διατροφής, που έχουν σχεδιαστεί για να μιμούνται τη γεύση, την υφή και την εμφάνιση των ζωικών τροφίμων. Συνήθως παρασκευάζονται από συστατικά όπως σόγια, σιτάρι ή πρωτεΐνη μπιζελιού. Παραδείγματα των παραπάνω είναι οι απομιμήσεις μπιφτεκιού, τυριού ή λουκάνικου. Ενώ οι καταναλωτές υιοθετούν ολοένα και περισσότερο στη διατροφή τους αυτά τα προϊόντα απομίμησης κρέατος και γαλακτοκομικών φυτικής προέλευσης, η διατροφική ποιότητα και η ικανότητα αυτών των τροφίμων να λειτουργούν ως υποκατάστατα σε επίπεδο διατροφής είναι ακόμα υπό συζήτηση και χρειάζεται περισσότερη έρευνα για την κατανόηση της διατροφικής ποιότητας αλλά και των μακροπρόθεσμων επιπτώσεων στην υγεία. Οι βάσεις δεδομένων σύνθεσης τροφίμων (FCDBs) είναι εργαλεία που παρέχουν λεπτομερείς πληροφορίες σχετικά με τη διατροφική σύσταση των τροφίμων. Χρησιμοποιούνται για διάφορους σκοπούς που σχετίζονται με τη διατροφή όπως ο προσδιορισμός της διατροφικής κατάστασης ενός πληθυσμού, η διερεύνηση πιθανής σύνδεσης της διατροφής με ασθένειες και ορισμένων διεργασιών της βιομηχανίας τροφίμων, όπως η διατροφική επισήμανση ή η ανασύσταση των τροφίμων. Η Ελληνική Βάση Δεδομένων Σύστασης Επώνυμων Συσκευασμένων Τροφίμων (HelTH), είναι ένα παράδειγμα βάσης δεδομένων σύνθεσης συσκευασμένων τροφίμων, που περιλαμβάνει δεδομένα για 4002 προϊόντα, από το 2020.

Σκοπός της μελέτης

Σκοπός αυτής της μελέτης είναι να επικαιροποιήσει και να επεκτείνει την βάση δεδομένων «HelTH», χαρτογραφώντας τις διαθέσιμες σήμερα απομιμήσεις κρέατος και γαλακτοκομικών προϊόντων στην Ελλάδα. Η επέκταση πραγματοποιείται περιγράφοντας τις απομιμήσεις κρέατος και γαλακτοκομικών ως προς το περιεχόμενό τους, αναλύοντας τα επιμέρους συστατικά τους, τους περιβαλλοντικούς ή ισχυρισμούς διατροφής, τους

δείκτες ποιότητας και τη θρεπτική τους αξίας. Κύριος στόχος είναι να συγκριθούν τα διατροφικά προφίλ αυτών των προϊόντων μεταξύ των διαφορετικών κατηγοριών που προκύπτουν λόγω των εναλλακτικών πηγών πρωτεΐνης, αλλά όσο και με εκείνα των αντίστοιχων ζωικών προϊόντων. Οι συγκρίσεις πραγματοποιούνται τόσο συλλογικά όσο και εντός των κατηγοριών διαφορετικής εναλλακτικής πηγής πρωτεΐνης, που αποτελεί το κύριο συστατικό κάθε προϊόντος. Ως μέρος της σύγκρισής τους με τα αντίστοιχα ζωικά προϊόντα, το σύστημα επισήμανσης τροφίμων «Nutri-Score» χρησιμοποιείται για να αναδείξει τις διαφορές μεταξύ τους. Η έρευνα περιλαμβάνει επίσης την ανάπτυξη ενός συμπληρωματικού ερωτηματολογίου - που δεν αποτελεί προτεραιότητα της τρέχουσας μελέτης - αλλά σκοπός του είναι να καταγράψει τη στάση και τις αντιλήψεις των Ελλήνων καταναλωτών απέναντι στα προϊόντα απομίμησης φυτικής προέλευσης.

Μεθοδολογία

Η διαδικασία συλλογής δεδομένων είναι μια κρίσιμη πτυχή της μεθοδολογίας της έρευνας. Οι πληροφορίες που προέρχονται από κάθε μεμονωμένη συσκευασία προϊόντος χρησιμοποιούνται για τη συλλογή λεπτομερών δεδομένων σχετικά με τα προϊόντα που μελετώνται. Τα δεδομένα αυτά οργανώνονται και κατηγοριοποιούνται χρησιμοποιώντας το σύστημα περιγραφής και ταξινόμησης τροφίμων Langual και EuroFIR. Οι πληροφορίες καταγράφονται σε υπολογιστικά φύλλα Excel, τα οποία επιτρέπουν την εύκολη οργάνωση και χειρισμό των δεδομένων. Για την παροχή πρόσθετων πληροφοριών και την αύξηση της εγκυρότητας της μελέτης, συμπεριλήφθηκαν νέοι περιγραφικοί παράγοντες στα αποτελέσματα ως μέρος της διαδικασίας επέκτασης. Αυτοί οι παράγοντες επιλέγονται με βάση τη συνάφειά τους με την πηγή πρωτεΐνης και την ικανότητά τους να παρέχουν μια πιο ολοκληρωμένη κατανόηση των δεδομένων. Το σύστημα διατροφικής επισήμανσης «Nutri-Score», η διατροφική σύσταση σε μακροθρεπτικά συστατικά, οι ισχυρισμοί διατροφής και τα χαρακτηριστικά ποιότητας συσκευασίας χρησιμοποιούνται για την αξιολόγηση όλων των προϊόντων. Τέλος, η στατιστική ανάλυση πραγματοποιείται με τη χρήση του λογισμικού IBM SPSS Statistics®, για τις συγκρίσεις και την αξιολόγηση των επιμέρους κατανομών.

Αποτελέσματα

Αρχικά εντοπίστηκε το κύριο συστατικό των προϊόντων. Αξιολογήθηκε η διατροφική τους σύσταση, η επικοινωνία προώθησης των προϊόντων (ισχυρισμοί διατροφής), καθώς και η συνολική διατροφική τους ποιότητα μέσω του αλγόριθμου «Nutri-Score». Αναλύθηκαν συνολικά n = 421 απομιμήσεις φυτικής προέλευσης. Αναφορικά με τις απομιμήσεις κρέατος, προέρχονταν κυρίως από μείγματα σιταριού ή σιταριού με σόγια (83,5%). Για τις απομιμήσεις γαλακτοκομικών κύρια πηγή ήταν αυτή των δημητριακών (19,8%) ή φυτικών ελαίων (17,1%). Όλες οι απομιμήσεις κρέατος ήταν πλούσιες σε πρωτεΐνες και φυτικές ίνες, ενώ για τα γαλακτοκομικά, μόνο τα γιαούρτια έφεραν ισχυρισμό περιεκτικότητας σε πρωτεΐνη (80,9%). Όλες οι απομιμήσεις γαλακτοκομικών προϊόντων είχαν χαμηλότερη περιεκτικότητα σε πρωτεΐνη από τα γαλακτοκομικά. Η διατροφική ποιότητα των απομιμήσεων κρέατος δεν εμφάνισε σημαντικές διαφορές σε σύγκριση με το κρέας, αλλά αυτό δεν συνέβη με τις απομιμήσεις γαλακτοκομικών, όπου ειδικά τα φυτικής προέλευσης τυριά βαθμολογήθηκαν ως D-E, σύμφωνα με το σύστημα «Nutri-Score», σε αντίθεση με το A-C για τα τυριά.

Συμπεράσματα

Αυτή η μελέτη εξέτασε το περιεχόμενο, τους ισχυρισμούς διατροφής, τους δείκτες ποιότητας και τη θρεπτική σύνθεση των απομιμήσεων κρέατος και γαλακτοκομικών σύμφωνα με την κύρια εναλλακτική πηγή πρωτεΐνης τους. Οι απομιμήσεις φυτικής προέλευσης περιλαμβάνουν συχνά ισχυρισμούς διατροφής στη συσκευασία τους. Τα προϊόντα με βάση το σιτάρι και τη σόγια είναι κατάλληλες πηγές πρωτεΐνης, ενώ αυτά με βάση το φυτικά έλαια δεν περιέχουν καθόλου πρωτεΐνη. Οι απομιμήσεις φυτικής προέλευσης έχουν ποικίλη σύσταση με βάση το κύριο συστατικό και η αντικατάσταση συγκεκριμένων ομάδων τροφίμων με φυτικές πηγές μπορεί να μην υποστηρίζει μια ισοδύναμη ή βελτιωμένη δίαιτα. Αυτή είναι μια πρόκληση τόσο για την ακαδημαϊκή κοινότητα όσο και για τον επιχειρηματικό τομέα, ο οποίος θα πρέπει να διερευνήσει νέες πηγές ή να αναθεωρήσει (ανασύσταση) τη σύσταση των υπαρχόντων απομιμήσεων ώστε να γίνουν πιο διατροφικά, φιλικά προς το περιβάλλον και πλήρως ισοδύναμα με τα ζωικά.

Επιστημονικό Πεδίο: Επιστήμη Τροφίμων και Διατροφή

Λέξεις κλειδιά

Εναλλακτικές πηγές πρωτεΐνης, απομιμήσεις κρέατος, απομιμήσεις γαλακτοκομικών, υποκατάστατα, φυτική διατροφή, vegan, διατροφική σύνθεση, βάση δεδομένων σύνθεσης επώνυμων συσκευασμένων τροφίμων, HelTH, επεξεργασμένα τρόφιμα, επισήμανση τροφίμων, διατροφική δήλωση, ανασύσταση τροφίμων

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I would also like to thank all my post-graduate classmates that participated in all of our weekly meetings and supported me in the research of my thesis by exchanging ideas and lastly the under-graduate student Aspa Mplougoura for her help on the food product data addition on the database.

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1. INTRODUCTION

1.1 Role of proteins in Diet and Food technology

Protein, fat, and carbohydrates play major roles in food systems due to their structural, mechanical, and other physicochemical characteristics. Protein is made up of amino acids is are necessary for life since the human body has high requirements for the amino acids found in exogenous protein sources for a variety of physiological processes, which in turn support our skeletal structure and metabolic reactions. It is considered "the most extensively discussed" macronutrient for feeding the world while is not only essential for stopping protein-energy malnutrition (PEM) and encouraging healthy muscle aging but also has large environmental consequences driven by its global demand. According to Gorska-Warsewicz (2018), human demand for protein is mostly met by food intake, and this protein at present is primarily derived from animal sources.

Food chemists have devoted a great deal of time to studying the physical properties of various types of proteins. Historically, these functional qualities have been nonnutritive, including foaming, gel formation, and emulsifying stability. More thorough research has shown that food-based proteins, whether animal-based or plant-based proteins, also play a role in flavor binding, color, allergenicity, and digestibility at a molecular level. Food proteins can create the intricate shapes that we recognize as food and may be connected to many qualities, nutritional availability, and bioactive bioavailability. Food formulators now are looking for solutions so they can substitute existing proteins in both new and old products totally or partially [1].

1.2 Animal based proteins are being displaced

The World Health Organization (WHO) defines as 'red meat' any mammalian meat (beef, veal, pork, lamb, mutton, horse, or goat), that is general consumed cooked, and as "processed meat" any meat that has been altered by any process (i.e. salting, curing, fermentation, smoking) for flavor or preservation needs [2]. Mammalian meat and dairy products have historically been significant sources of protein for people and the human diet supplying the body with all necessary nutrients including protein, lipids, vitamins, and minerals [3,4]. Animal proteins are more digestible than those derived from Plants, better ordered and usually tend to be fibrillar or fibrous structures, while in plants, globular, less organized proteins are found [5]. Dietary habits of consumers have a tremendous impact on both global and individual health and hence the global meat market is estimated to grow at a compound annual growth rate of 7.35% per year by the end of 2025 [6]. In addition, according to predictions, the global population could increase from 7.7 billion in 2019 to as many as 8.5 billion by 2030 and up to 9.7 billion by 2050. Current market trends are generating interest in alternative protein sources. The European Union (EU) has investigated prospects for producing EU protein plants that offer benefits to the economy and environment (European Commission 2018). Farm to Fork Strategy aims to lessen reliance on commodities cultivated on deforested lands, such as soy, in favor of alternative plant proteins grown in the EU (European Commission 2020). Consequently, one of the many potential answers to health and environmental problems is to replace meat consumption with other protein sources. A trend toward a plant-based diet seems to be a first step in lowering the Western world's excessive meat intake. With more than 6485 product innovative products worldwide since 2015, plant-based meat and dairy substitutes (also called alternatives, imitations, analogs, mock meat, faux meat -are plant-based products that mimic the appearance, flavor and the texture of animal meat or dairy products) are notably flourishing on the market and tend to be more and more established [6-8].

1.2.1 Types of current plant-based diets and the Mediterranean diet

All animal products are excluded from vegan diets, including meat, dairy, fish, eggs, and (often) honey. Diets that are lacto-vegetarians don't include dairy items such as milk, cheese, yoghurt, and butter but do omit meat, fish, poultry, and eggs. Eggs and dairy are included in lacto-ovo vegetarian diets, but fish and meat are not. Ovo-vegetarian diets allow eggs but prohibit meat, poultry, fish, and dairy products. Pesco-vegetarian (or pescatarian) diets contain fish, dairy, and eggs but not meat. Semi-vegetarian (or flexitarian) diets are largely vegetarian but occasionally or in limited amounts include meat, dairy, eggs, poultry, and fish.

The traditional Mediterranean diet (MD) has been adopted as a healthy eating pattern throughout Europe and all over the world. It recommends high consumption of plant-based foods (cereals, legumes, nuts, fruits, vegetables, and herbs), while limits red and processed meat. It comprises a moderate amount of fish, seafood, eggs, white meat, and dairy products, a moderate intake of alcohol, and olive oil as the primary source of added fat. In comparison to the previous 2011 version of Mediterranean Diet Pyramid (MD-P), the new sustainable version of MD-Pit is emphasized on reducing the consumption of red meat and dairy products while increasing the consumption of locally cultivated eco-friendly, in-season derived plant-based foods [9–11].

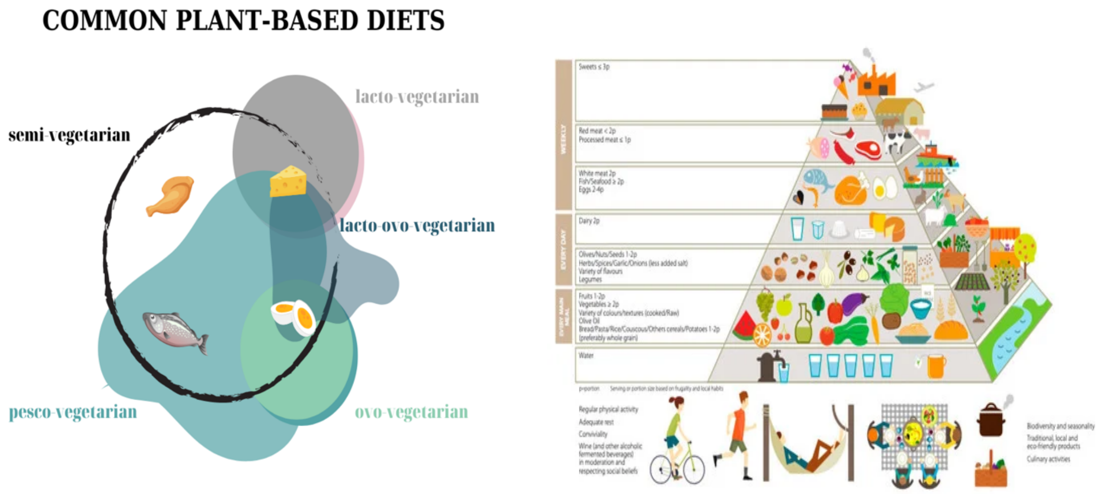

Figure 1 Common plant-based diets (on the left) and the new updated Sustainable Mediterranean Diet (on the right) [12]

1.2.2 Reasons for shifting to plant-based sources of protein

More and more people are switching to plant-based diets for health, ethical grounds related to climate change, health and animal welfare reasons [10,13–21]

<u>*Health*</u>

It has been found that plant protein consumption is linked to significant health benefits which includes lower risk of heart attack or strokes. On the contrary, low fruit and vegetable consumption is associated to increased risk of Non Communicable Diseases such as heart disease, cancer, chronic respiratory disease and diabetes. Overall, the data points to a preventive impact of vegetarian and vegan diets against coronary heart disease; however, more recent investigations have found an elevated risk of stroke. So far, cancer but more specifically, bowel cancer is the most strongly linked to nutrition since overconsumption of processed or red meat enhances the risk of it. According to research, those who consume less meat or no meat may be less likely to develop diabetes, due to their lower BMI (Body Mass Intex), which is the most important factor for obesity. Substituting 3-5% of animal protein calories with plant protein reduced mortality from all causes, cardiovascular disease, and dementia). Lower blood pressure, decreased LDL, improved insulin, lowered risk of diabetes, and lower levels of IGF-1, a hormone associated with increased risk of several types of cancers, are some of the most important beneficial outcomes of plant protein consumption that have been studied over the years. Although the data mentioned above may indicate that plant protein may be healthier than animal protein, plant-based meat imitations are frequently made with highly processed protein ingredients like protein isolates, which may have lost some of the health benefits associated with the consumption of whole-plant foods.

Socioeconomic

Food security is one the Sustainable Development Goals of Food and Agriculture Organization of the United Nations' and hence there is a need of more sustainable food sources with micro- and macro-nutrients. Animal, vegetable, and microbial proteins are crucial to meeting the world's supply needs of protein, and the diversity of protein sources and functions is critical for food safety, product development, and production in order to fulfill customer expectations and individual food needs [22]. Adoption of plant-based diets might result in billions of euros in healthcare cost reductions across Europe, in addition to the advantages to human health. Health-care systems are burdened by excessive meat eating and in 2020 there were 2.4 million deaths and 240 million euros spent in medical expenses worldwide that were assigned to overconsumption of red and or processed meat. "Actor designation," the process of identifying all stakeholders including people, organizations, and groups (international organizations, governments, civil society organizations, corporations, academics, and consumers) having a commitment to meat reduction and who use and amass influence within the system, is the first stage of a political economy study. These players' interests in meat reduction might be either private (like sustaining business profits) or public (such promoting health, lowering healthcare expenses, and protecting the environment), or perhaps both (such as economic growth) [2].

Environmental

> *«A sustainable food system is a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised»*
>
> *"Sustainable diets are those 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*

Definitions of sustainability often address issues related to nature, the economy, and society. For consumers, a sustainable diet may not always mean the same thing as for farmers or manufacturers. The FAO defined sustainable diets as ones that "contribute to food and nutrition security and a healthy life for present and future generations while having low environmental implications". Sustainable diets are "nutritionally adequate, safe, and healthy; protective and respectful of biodiversity and ecosystems; culturally acceptable, accessible, economically equitable, and inexpensive; and maximize natural and human resources.

Six priority areas have been established by FAO as part of the Strategic Program on Food Systems with the last being more inclusive and effective, ensuring a better understanding of how changes in the food system can affect various SDGs. One of the six priority areas of FAO are: Sustainable Food Systems. Food production has been affected by serious changes in food and water insecurity, which are constantly have impacted by agricultural yields reduction due to climate changes. However, it should be highlighted that the food chain is one of the primary drivers of these changes in the ecosystems. The food industry is responsible for 30% of all anthropogenic greenhouse gas (GHG) emissions and 70% of fresh water use (AQUASTAT data, 2017). One of the main drivers of land use change and biodiversity loss is the food industry. Reducing food losses and switching to more sustainable agricultural technologies have been suggested as solutions to this problem. These steps, however, are not enough if no shift in food preferences among the general population exists. In high- and middle-income environments, research has shown that switching from animal products to plant-based sources of food may significantly lessen environmental effects. The evaluation of the carbon footprint of meat substitutes has been the subject of a few articles. Each agreed that meat analogs are a more environmentally friendly substitute for meat and processed meat products [23,24].

1.3 Alternatives sources of protein

1.3.1 Main imitations

Meat and dairy imitations have been developed. Plant-based proteins like cereals, legumes, seeds, nuts, potatoes, mushrooms, insects, cultured meat, seaweed, Single Cell Products (edible proteins originating from different microbial sources: bacteria, algae, yeast, fungi) are some of the main sources that are being used for the formulation of them. Many imitation categories of original animal-based products have been developed recently.

Meat imitations are meat-free products appearing to mimic any kind of mammal meat. Generally, they contain water (50–80%), vegetable protein (textured or not), (10–45%), flavorings (3–10%), fat (0–15%), binding agents (1–5%) and colorants (0–0.5%). The final product's texture can be improved by adding additional certain components. Soy (tofu, tempeh, textured soy protein), gluten (seitan), legumes (peas, lentils, lupine, chickpeas) and seeds (rapeseed, canola) are the most common vegetable sources [9,25].

Vegetable drinks or milk imitations, are plant-origin drinks where the plant source is extracted in water for further homogenization. Seeds (sesame, sunflower), legumes (soybean), cereals (oats, rice), pseudo-cereals (quinoa,), nuts (almond, walnut, cashew, hazelnut) and fresh or dried fruit (coconut) are used for the formulation. They tend to have high water content and different viscosity depending on the kind.

Cheese imitations are products made from lipids and/or proteins of plant origin (soy or peanuts) (soy, coconut, tapioca, nutritional yeast, nuts)[25]. The development of cheese imitations requires alternative protein and/or fat sources to those used in conventional products and attempting to replicate the distinctive characteristics of cheese. Different formulations of alternatives to conventional cheese exist either using caseinates and vegetable oils or formulations that totally excludes milk and use plant-based ingredients. In the manufacturing of these items, acids, flavorings, and salts are other frequently utilized components.

Fish imitations include products, ingredients, or a combination of ingredients used as a substitute for fish: soy, gluten, algae, mushrooms and vegetables (rice, tubers, potatoes, etc). To be able to mimic the natural characteristic of fish the fibrous gel structure has to be imitated from cellular tissues and from the organization of protein chains. To achieve that, by replacing partially or totally of the raw material of fish or myofibrillar proteins of fish transforming it to “surimi gels”.

Mung bean protein is the component that gives the cooked "egg" its semi-solid consistency. Curcumin from turmeric and carotenoids from carrots give these items their yellow color. Finding a mixture of plant proteins that aggregate and unfold across a comparable temperature range as egg proteins (about 63 to 93 °C), that provides a similar texture-temperature profile, and that results in a similar final look and texture is crucial for developing egg mimics. Pea, chickpea, bean, soybean, and sunflower proteins are among the plant proteins that may form gels when heated above their thermal denaturation temperatures. However, the protein structure, protein concentration, pH, salt, and temperature conditions must be carefully managed.

1.3.2 Protein sources

For the creation of imitation products, many and various types of alternative protein sources are used, each with a different collection of characteristics. Grains and cereals, legumes, pulses, nuts, potatoes, seeds, mushrooms, insects are some of the many alternative sources that are typically used.

Wheat (Triticum aestivum), is a global staple food. Wheat grain contains monomeric and polymeric proteins with varying solubility and structures. Polymeric proteins are mostly insoluble glutenins, while monomeric proteins include water-soluble albumins, salt-soluble globulins, and alcohol-soluble gliadins. Through extrusion create texturized wheat protein at high shear, high temperature, and low moisture, into a meat-like fibrous structure. Texturized wheat proteins are utilized in ready-to-eat meals as meat extenders or with heat-gelling proteins like egg white and soy isolates [5]. Wheat is easily available and used with soy in meat replacements for texture. Gluten, dairy, soy, and nut-free products are in high demand. Over the past five years, EU oat product releases have increased. That's why oat replaces dairy products notably in yogurt, sweets, and milk alternatives. Oat-based dairy replacements usually provide less protein than dairy products.

Quinoa (Chenopodium quinoa wild), a native Andean annual herbaceous flowering plant, is grown for its edible seeds Quinoa is a dicotyledonous plant, not a cereal like wheat, rice, or barley. Quinoa grains have 14–18% protein and a balanced number of essential amino acids like lysine, threonine, and methionine. Prolamin proteins are few in quinoa proteins, which are mostly albumins and globulins. Their grains can be used to make protein-rich, gluten-free health products because of their protein composition. [5]

Rice (Oryza sativa) was once referred to as "gold of the Orient" and is the most frequent staple food consumed by about half of the world's population. In 2017, the worldwide average per capita rice consumption was close to 54 kg, while its consumption exceeded 100 kg per capita in a number of Asian nations. Rice accounts for around 20% of global human caloric intake and up to 16% of daily protein needs, making it the second-most significant cereal crop for human nutrition after wheat. Rice proteins are commonly used in infant formulae and gluten-free value-added plant-based products. It is commonly used to either meat or dairy imitations.

Soybeans (Glycine max) belong to Fabaceae. Soybeans provide high-quality protein (36%), soluble and insoluble carbohydrates (30%), lipids (18%), and other plant components, including micronutrients (16%). Many food products use soy proteins for their nutritional and functional benefits. Soy protein replacement with animal-based proteins reduces food formulation costs and meets food supply chain sustainability criteria for high-quality protein. It is a common plant-based ingredient and alternative to animal proteins that remains an important alternative to meat and dairy. Chicken nuggets and beef patties substitute 30%–40% of meat with soy protein. Soy protein replacement products look and taste like meat and provide lean meat-like protein. In spite of this, soy protein has lower concentrations of numerous essential amino acids compared to animal-derived foods, particularly methionine and lysine.

Textured soy protein can be colored with spices and malt extracts and absorbs natural or synthetic tastes to enhance product flavor. Soy protein replacement products maintain their water holding capacity during cooking, freezing, and at high temperatures than animal products manufactured without added plant-based proteins.

Defatted soy flour is used to make soy protein isolate, the third form commonly used in imitations (SPI). SPI is less flatulent than raw soy flour and has ~90% protein by weight. SPI are mostly used in food to improve water retention, meat texture, and protein content.

Functionally, soy protein isolates and concentrates are superior to unprocessed or minimally processed soy protein due to improvements in color (minimally processed soy protein typically darkens meat products) and flavor (minimally processed soy protein typically imparts a bitter taste). Most manufacturers though use a combination of textured and non-textured soy protein for both nutrition and functional purposes [4,5].

Lastly, the rising availability of other plant-based alternatives, concerns regarding the sustainability of soy, and its designation as an allergy may push the adoption of alternatives. According to Innova statistics (2016-2020), the EU's usage of soy remains basically steady (Innova Database 2021).

Pulses are Leguminosae crops that are only collected as dry seeds. Pulses serve a significant function in the provision of plant proteins in a sustainable and cost-effective manner. Pulses are referred to as "poor man's meat" in several nations due to their comparative affordability with meat and meat-based products [5]. In contrast to legumes, such as peanuts and soy, pulses are nutrient-dense foods with high protein and fiber content and relatively low lipids. The primary advantage of pulse proteins over cereal proteins is that they are gluten-free and rich in important amino acids such as lysine, making them acceptable for gluten intolerance and celiac disease sufferers. Pulse proteins are predominantly constituted of globulins and albumins, with the latter being the most amino acid-rich protein. Refined pulse proteins as concentrates or isolates are commonly utilized as nutritional supplements and ingredients in novel and traditional food products, and the creation of imitation milks, drinks.

Pea protein, is an upcoming alternative protein. Textured pea protein and functionalized isolates were introduced to the market making pea isolates concentrates, and functional pea flours the major forms of pea protein in the food products . Due to its mild allergenic profile in comparison to soy and wheat, it is an emerging alternative source.

Chickpeas, have been suggested as a soy-free option to plant-based dairy substitutes. They're among the top 15% of plant-based proteins. Chickpeas are being used further into innovative food and plant-based alternatives both food and beverages. The lipid content and LOX-catalyzed degradation of polyunsaturated fatty acids in these legumes are thought to create undesirable off-flavors. [5,26]

Nuts are recognized for their high levels of protein, minerals, and vitamin E, which is considered to have antioxidant characteristics. In addition, they contain phytosterols that inhibit the absorption of dietary cholesterol. Notably, its lipid level is one of the highest among plant-based foods. The bulk of the lipids present in nuts, drupes, and seeds are healthy unsaturated fatty acids. In addition to their nutritious value, this category of raw materials has higher consumer acceptability than other raw materials due to their naturally nutty flavor, which is more compatible with conventional dairy flavor than the bean-like, earthy flavor of grains and legumes. Almond (Prunus amygdalus) and coconut (drupe- Cocos nucifera) are two of the most often used dairy alternatives in this category (Cocos nucifera). Almond has a naturally creamy texture, making it a perfect substitute for cow's milk and products produced from it. Coconut offers a significant advantage over nuts as a raw material for dairy substitutes because it does not include allergies typically found in nuts. In general, their exceptionally high and protein-rich composition has led to the widespread use of nuts and drupes as dairy substitute raw materials. Hard-shelled dried fruits are nuts. Typically, commercial almond milk is flavored with vanilla or chocolate and fortified with calcium and vitamin D [26].

Potato protein is already utilized as a food ingredient in the European market. It can be used as a vegetable-based emulsifier and is a low-allergenic substitute for soy and wheat.

Oil seed crops, including rapeseed and sunflower seeds, are recognized as rich sources of plant proteins. Various food products have utilized the extracted fraction of rapeseed and sunflower seed proteins to achieve better nutritional profile of their final products. Rapeseed (Brassicaceae family), cultivated for its oil seeds, has approximately 17–26% protein and the isolates contain at least 90 percent protein being viable alternatives to other plant-based protein sources. Because rapeseed proteins are readily available in a enough amount of all of the essential amino acids, they can also be used in the preparation of gluten-free baked products, and sausage-like products.

Sunflower seeds are utilized for oil production, although dehulled sunflower seeds have a greater protein content (20–40%). It has been suggested that sunflower protein be added to fortify a range of foods, including infant formulae, milk, meat, and bakery products.

Mushrooms are regarded a potential ingredient due to their health-promoting qualities. Knorr and WWF list enoki, maitake, and saffron milk cap mushrooms as top 50 future foods. The CBI reports substantially increase in the European dried mushroom industry due to rising interest in vegan and vegetarian diets. Moreover, EU commerce depends on ethical and sustainable mushroom production.

Products rich in proteins, carbohydrates, lipids (eicosapentaenoic (EPA) and docosahexaenoic (DHA)) fatty acids and other bioactive compounds, algae, are being developed for alternative sources. However, digestion and bioavailability might be hindered by the cell wall, which prevents nutrients from being utilized. Some examples are: Chlorella spp., Arthrospira spp., and Schizochytrium spp.

Insects, are products rich in proteins, with essential amino acids in their composition. Due to the presence of chitin, which provides insect proteins stiffness and makes them resistant to breakdown by digestive enzymes, insect proteins are poorly digestible. Thus, insoluble precipitates may form, reducing the bioavailability of minerals and the digestibility of proteins. Furthermore, the presence of significant quantities of hydrophobic amino acids limits the usage of insect proteins in food production applications due to their low solubility.

Lastly, lab -grown meat is produced by cultivation in animal-cells in vitro. This technology makes it possible to produce meat yet avoiding large-scale livestock rearing [6, 26-29].

1.3.3 Other sources

Traditionally, meat analogs have a low lipid content; however, modern meat analog products have a significantly higher lipid content than conventional meat analog products. In reality, the lipid content of current meat imitations is comparable to that of traditional meat products. Similar to the method employed with protein ingredients, meat mimics are typically produced using a variety of lipid substances (fats/oils). Canola (rapeseed) oil, coconut oil, sunflower oil, corn oil, sesame oil, cocoa butter, and many other vegetable and plant oils are employed as lipid components in modern meat substitutes. According to a previous review by Kyriakopoulou , the role of fats and oils in meat analog formulations is to contribute to the juiciness, tenderness, mouthfeel, and flavor release of the product; however, significant consideration should be centered on the effect of the fats and oils during processing and preparation in order to prevent excessive lubrication and stickiness. The fatty acid composition of fat and oils is certainly variable between sources and manufacturing methods.

Carbohydrates are not found in meat unless the meat product is further processed and additional carbohydrate ingredients are added, which is a practice that is actually rather prevalent in the processing of meat, particularly in emulsified and formed processed meat products. Products that are considered to be meat analogs, on the other hand, virtually usually contain carbohydrates. The carbohydrates that are contained in meat analog products can originate from a wide variety of different ingredients, and those ingredients can perform a wide variety of functions throughout the manufacturing process.

Polysaccharides play key structural and functional roles in the formation of meat analogs due to their thickening/emulsifying capabilities, which are typically required to increase the consistency and water binding. Native starches and flours (such as potato, corn, wheat, cassava, pea, and rice) are mostly employed as fillers to improve texture and consistency. Fibers from various sources (e.g., pea, potato, oat, soy, bamboo, citrus, and apple) and polysaccharide gums (e.g., xanthan gum, gum arabic, carrageenan, and alginate) permit thickening and reducing cooking loss of the product due to their high water-holding capacity by forming stable oil/water emulsions.

In the same way that flavors and spices are added to the majority of processed and prepared foods, they are also added to meat imitation products. To achieve the "meat-like" flavor in meat substitutes, numerous ways have been explored. As described by Kyriakopoulou in their review, the isolation of particular naturally occurring volatile chemicals, often in conjunction with various thermal processes, is the most common way for capturing the flavor and fragrance characteristics of meat products. After comprehensive testing, these flavor components are subsequently integrated into meat mimic compositions at the proper levels.

Meat color influences consumer buying intent. The proteins that give meat its color, chiefly myoglobin, undergo chemical changes during cooking, changing the hue from brilliant cherry red for beef, reddish pink for pork, and bluish-white to yellow for poultry. For meat analogs, color and color change during cooking are very important factors. Meat analogs should have the same hue before, during, and after cooking. Modern meat analog products' coloring components differ. The general formulation concept is to use additives that mimic the meat's natural hue. Beet juice extract lycopene and/or tomato paste are commonly used. Sarcoplasmic proteins, which are chemically similar to myoglobin, the iron- and oxygen-binding protein in muscle tissue, are employed to generate a meat-like color [4,6].

The nutritional content of meat and dairy imitations can be improved with the addition of various fortification ingredients, such as minerals, amino acids, and vitamins. In order to enrich the products for the daily recommended intakes, these could additionally include tocopherols, zinc gluconate, thiamine hydrochloride, sodium ascorbate, niacin, and pyridoxine hydrochloride. Riboflavin and cobalamin are also included. In addition to the positive effects that these compounds have on health, they also have the potential to exert significant influences on the quality, storage, and oxidation of lipids in meat imitations. Microalgae, mushrooms, and pulse flours are examples of pure ingredients or matrices that include vitamins and minerals added to them. In addition to proteins, non-protein compounds have a large part in the solidification and flavor of meat imitations. This function is primarily due to the fact that proteins are the building blocks of muscle

1.3.4 Manufacturing of plant-based imitations

Plant-based sources, such as grains, legumes, and seeds, can be used as entire ingredients and protein concentrates in meat and dairy substitutes. Significant structure-function correlations exist between proteins and their hydration and solubility, interfacial properties (emulsification and foaming), flavor binding, viscosity, gelation, texturization, and dough formation. Moreover, processing induces physical, chemical, and nutritional changes in proteins, food safety hazards (allergens), anti-nutritional factors, processing contaminants, or even microbiological quality, which vary according to the protein source.

Protein from plants, if they are not used as an entire ingredient, can be derived using either dry fractionation or wet fractionation. The selection of technology is dependent on crop composition (protein, oil, and starch content).

Dry fractionation is typically used to starch-containing crops such as pea, fava bean, utilizing air classification, a technique that separates materials based on air velocity and particle size. As a result protein concentrate is produced. The protein content is determined by the protein and starch content of the beans or seeds, the size disparities between the protein body and starch granules, and the milling efficiency. This method enriches anti-nutritional substances, such as plant phenolics (tannins), and protease inhibitors. Toasting, which is often used in soy processing to inactivate enzyme and protease inhibitors and create positive off-flavors, is one example of a method for mitigating this issue (the conditions depend on the crop and whether dry or wet toasting is used

Wet processing is a typical processing method for producing protein isolates. It is mostly utilized in oilseed and pulse processing to produce a protein isolate. In the case of oilseeds (such as soybeans or rapeseed/canola), defatting is necessary (by pressing or hexane extraction). It contains, in a simplified manner, a hydration stage, a decanting process to remove starch and insoluble fiber, an isoelectric precipitation step to extract the globulin fractions of the proteins, and a spray-drying phase. A high protein purity of the components allows for more formulation flexibility and the elimination of antinutritional elements (mainly during the isoelectric precipitation step). Proteins from cereals (such as wheat gluten) are removed using a simple water-washing procedure (to remove the starch). In the majority of instances, potato proteins are recovered from the potato fruit juice (after starch and fiber extraction) by an acidic-heat treatment (90-105 °C), resulting in low-added-value proteins for use in animal feed [25].

Once proteins are isolated from plants, more processing is required to create meat and dairy imitations from these proteins. Extrusion is the primary process utilized in the production of meat analogs, either to produce texturized vegetable proteins used in, for example, burger patties or to make high-moisture meat analogs such as chicken parts. Utilizing high-moisture extrusion to generate fibrous structures to meat is a crucial step in the development of soy-protein-based meat imitations. In addition to this application, allergenicity, odor, and the production of off-flavors during processing impact its viability as a meat imitation [6,25]. Texturizing techniques for the production of meat and dairy imitations, respectively are described below (Tables 1,2):

Table 1 Texturizing techniques for the production of meat imitations

Technology	Short description
Extrusion	Extrusion is the most common patented protein texturization technology due to its high productivity, cheap cost, adaptability, and energy efficiency. Extrusion denatures heat-labile anti-nutritional factors including trypsin inhibitors and hemagglutinins, inactivates hydrolytic enzymes such as lipoxygenases, peroxidases, and lipoxidases, and increases protein digestibility. Shearing, heating, compression, and cooling during extrusion affect protein conformation (denaturation, unfolding, crosslinking, and alignment) to create meat-like structures (structured aggregates or fibrils)
High temperature induced shearing	High-temperature induced shearing texturized plant proteins easily, mildly, and cheaply. Cone-on-cone and cylinder-in-cylinder devices ensure shear-induced protein structure. The cone-in-cone mechanism heats the product from both sides in an oil bath at high shear stress and temperatures (95–140 °C). The bottom cone rotates while the upper cone is motionless. The cylinder-in-cylinder device creates similar shear flow to the cone-in-cone device by placing the product between two cylinders, one stationary and one spinning. Due to simple shear and heat, shear-induced structuring produces defined fiber structures compared to extrusion. Shearing at 140 °C produced a solid asymmetric food texture, while low temperatures produced a layered structure.
Electrospinning	High-voltage nanometer-scale (very thin) fiber production. The grounding electrode's electrical potential gradient accelerates the protein solution via a nozzle. The nozzle jet forms a fine fiber

	(100 nm) as the solvent evaporates and is collected in the collector.
Mixture of proteins and hydrocolloids	Combining plant proteins and hydrocolloids is also a usual method. A mixture of water, a vegetable fat or oil containing a protein (such as lupine protein, pea protein, potato protein, or rape protein), and hydrocolloid(s) (such as sodium alginate and methylcellulose) is sheared to produce a stable emulsion and a colloidal solution of divalent metal cations, fibrous materials are cleaned and pressed to remove excess water, resulting in 40%–60% dry matter. Casein and alginate can be employed with multivalent cations in this method.
Freeze structuring	Freeze structuring or freeze alignment involves freezing the aqueous solution (protein paste) to structure it. During this procedure, proteins are mixed with other components until a homogenous emulsion is produced. This mixture was then shaped, frozen (to produce ice crystal layers), then dried (steaming, baking, or frying). Without melting the ice crystals, drying at a high temperature solidifies the protein's fibrous texture (irreversible, significantly insoluble form). By modifying freezing conditions, proteins' textural qualities can be altered.
Bioprinting/3D printing	Three-dimensional food printing is rapidly developing with various 3D printing techniques available. This technology is based on the extrusion of a paste consisting of plant proteins and other components (such as water, lipids, and polysaccharides) through a fine nozzle to create multilayer blocks. This method permits the creation of products with a texture resembling muscle fibers and a specific nutritional profile.

Since plant proteins have inferior solubility and functionality (particularly gelling qualities), they require the addition of starch or other hydrocolloids in order to be processed into or used as dairy imitations. The production techniques of plant-based beverages vary based on the raw ingredients utilized. Initial consideration must be given to whether the specified raw material should be or not peeled. Whether the material is peeled or unpeeled, dried or fresh, the second step is that it has to be subjected to dry roasting or grinding. In case of fresh material, it must be immersed in hot water to remove the peel. Following peeling, the preparation must be dried. Alternatively, if the product is already dried, it is immediately subjected to dry roasting or grinding [25]. Further details on the production (Table 2) and the functionality (Table 3) of dairy imitations are listed below:

Table 2 Technological processes for the production of dairy imitations

Production stages of plant-based drinks	Short description
Roasting	Applied in peanut, sesame, and hazelnut beverages; Roasting improves the stability of emulsions and the solubility of proteins; It can decrease acidity, total solids, protein, and fat, as well as reduce bitterness.
Dry grinding	Wet grinding is a substitute for dry grinding, although it is not the preferred method.
Peeling	Utilizing acids or bases. Using citric acid (2% concentration at 90°C for 2 minutes) and sodium hydroxide (NaOH) as a base, the nut is peeled. Utilization of water is possible, and the procedure is lengthier (18 to 20 h). The time required varies on the basic materials utilized. A further wash should be performed to eliminate any remaining acid or base. Peeling enables the removal of the skin's poisonous components, hence eliminating the bitter flavor.
Soaking in water	Used for soybeans, hazelnuts, rice, sesame, peanuts, and almonds; raw materials undergo hydration (soaking) and softening. The stage includes the release of toxins and nutrients into the water.

Blanching	Used for soy, almond, coconut, sesame, peanut, rice, and quinoa; Reduces microbial load; Inactivates enzymes; Blanching with steam may be employed (increases total solids and protein yield)
Wet milling	Used on soy, coconut, cashew nuts, hazelnuts, hemp seeds, almonds, walnuts, and peanuts. Some of the variables that influence the final product are the amount of water used, the grinding temperature, the pH, and the type of grinding.
Filtration	It is used to separate the liquid phase from the solid phase of the ground raw material; Use double-layer gauze or filter paper of various diameters for filtration.
Addition of ingredients	In order to strengthen the stability of solutions, many stabilizer and thickening fator are used. For example sunflower lecithin, locust bean gum, and gellan, xanthan gum. The addition of ascorbic acid prevents oxidation. Sweeteners (sugarcane, sugar syrup, and sucrose) and sea salt are added to enhance the flavor of the product (some varieties may also include vanilla or cocoa). To enhance the appearance of silkiness, sunflower oil and olive oil are used too.
Fortification and enrichment	Various substances are included during manufacture to improve the nutritional and organoleptic qualities of the final product. Calcium and vitamins (A, B2, B1, B12, D2 and E) are added to increase the mineral and vitamin content. Calcium citrate is utilized to enhance the calcium content of the finished product.
Homogenization	It seeks to improve the product's stability; at this stage, the product's temperature can rise between 5 and 10 degrees Celsius.
Sterilization and Pasteurization Aseptic packaging and cold storage	Sterilization and pasteurization can be utilized with the aim of extending the product's shelf life.

	Maintain the product's shelf life has to be done at storage temperature +4 degrees Celsius.

Among the common ingredients in these products' processing, acids, flavorings agents and salts are also used. Great example are cheese imitations (Table 3 - adapted from [25]).

Table 3: Cheese imitations functions and ingredients (adapted from [25]*])*

Function	Ingredients
Composition and texture required	Fat, proteins : soy, corn, casein, whey, caseinates
Lower price relative to casein	Vegetable proteins : peanuts gluten starch (rice, potato, natural or modified corn)
Texture and stability	Hydrocolloid stabilizers :sodium phosphate, sodium citate, guar gum, xanthan gum)
Flavor	Flavorings or flavor enhancers(smoked extract, spices, cheese-modifying enzyme, yeast extract)
Self life extension	Preservatives

1.4 Nutritional value of imitation products

Concerns exist regarding the nutritional sufficiency of plant-based diets. Without a question, plant-based diets, whether they contain meat and dairy imitation products or not, have nutritional limits. Although the absorption and bioavailability of certain micronutrients (such as iron, vitamin A, and zinc) may be lower in plant foods than in animal foods, it is still possible to receive the necessary levels of these micronutrients with a plant-based diet that includes a range of plant foods. As for other micronutrients, such as vitamin D and vitamin B12, which are mostly derived from animal sources, plant-based eaters may choose to consume fortified meals. Individuals who adopt a vegan diet should be cognizant of the possibility of vitamin deficiencies. Vegan diets typically meet protein intake recommendations, albeit with a lower protein content than less restricted plant-based diets. It should be highlighted, however, that the existing research in this field is based on a limited number of cohort studies [30]. Another issue occurs when examining plant-based proteins is the amino acid profile of the providing source. For example, the majority of cereals contain low lysine levels and high methionine levels while pulses or legumes the opposite, making these two plant-based group foods complimentary. The amino acid composition of a product comprising both cereal and legume protein is therefore thought to be more balanced [31-34].

1.5 EU food law: Regulations that impact innovative food in EU

The Novel Food Regulation, the GM Food Regulation, the Food Information Regulation, the Nutrition and Health Claim Regulation, and the Organic Food Regulation are the principal European food regulations that have an impact on the revolution of alternative proteins [35].

There are three principles of regulation on novel food set by EU: i) safe for consumers; ii) novel products must be appropriately labeled, to avoid misleading the consumers; and iii) novel food should not be nutritionally disadvantageous when intended to replace by any means [36].

A claim is defined as "any message or representation that is not required by Community or national legislation, including any pictorial, graphic, or symbolic representation, that declares, implies, or leads to the conclusion that the food has special features." Health claims were introduced in the EU regulation in 2004, while Codex Alimentarius maintenance claims were given in 1997. New Regulation 1924/2006 of the European Parliament and Council on nutrition and health claims on food sets explicit criteria and guidelines for the use of previous claims promoting consumer protection and fair trade. False claims that are typically non-authorized and utilized by manufacturers can frequently mislead consumers. Additionally, statements, symbols, logos or images that express environmental characteristics of a product are referred to as "environmental claims". In the Circular Economy Action Plan, the Commission proposed that enterprises should verify their environmental claims using EU Product and Organization Environmental Footprint methodologies, using environmental impact categories to evaluate a product or company's environmental performance from raw material extraction to end of life [37].

The Food Information Regulation EU/1169/2011, which specifies labeling requirements for all foods including plant-based products, is the primary piece of food legislation. The food product's ingredients must be listed in descending order by weight, GMO foods must be labeled (if they contain at least 0.9% GM materials), allergies must be clearly identified, and nutritional data must be provided. Plant-based product naming and labeling regulations have generated controversy and rendered some investments useless. Health claim regulations are quite rigorous, and the process is difficult. In labelling, leaflets, and advertising, any false or deceptive marketing claim are forbidden (Food Information Regulation, Article 7). Organic Food regulation is the only one that permits the labeling of an alternative protein product as ecologically friendly.

The name of the food must be visible on the package. The legal, customary, and descriptive names are the three categories of food names that EU legislation defines. The first required detail is the name of the food, often known as the "sale description" or the name under which the product is marketed which has to be its legal name (Article 17 and Annex VII). If no such legal name exists (like in the plant-based imitation cases) the name of the product must be customary, which has to be accepted and recognized by consumers. If not legal nor customary name is available a descriptive name is required. Additionally, general labeling criteria are being used by EU food regulations. These have to do with the protection of particular phrases, including milk, cheese, hops, milk, pork, beef, chicken, and so on (European Commission 2008; Case C-1 95/14, Tee- Kanne 2015). These terms are protected from substitution by similar components, for example, and are defined in the regulation. The growing market of alternative proteins including plant-based "substitutes" do not easily fit inside the parameters of current EU food law.

Most of the current law is created to defend the economic interests of significant agricultural industries once the Common Market and CAP were developed, but secondary protecting consumers from food fraud and unintentionally purchasing inferior substitute items was also deemed crucial.

In the case of milk products, terms like milk, cheese, and cream are only used to describe items made from mammary secretions. The European Court of Justice has discussed the naming of vegan dairy substitutes, and from 2017, it decided that the reserved dairy names cannot be used even when paired with clarifying descriptions like "vegan" or "plant-based". This is because Common Agricultural Policy (CAP) has as main purpose, for both producer and consumer perspectives, to improve the economic conditions for the production and for the marketing of original dairy products. The EU law on milk product names allows for exceptions for products "whose precise nature is obvious from customary usage (i.e almond milk and coconut milk). The Court determined that the broad EU laws against misleading consumers are insufficient in the case of milk products [35].

Rules for meat products are different from those for dairy ones. The names for the various types of meat—beef, pig, and chicken—as well as the word "meat" itself are protected, but those for the shapes and ingredients of meat products—steaks, sausages, and burgers—are not. Although In April 2019, a reformulation proposal of the CAP was attested by the (COM/2018/0394), limiting the use of the words 'steak', 'sausage', 'escalope', 'burger', and 'hamburger for animal-based products only, it was rejected by the whole EU Parliament in a vote on October 23, 2020.

In the lack of legally specified "meaty" names at EU level, companies have turned to the law of the Member States, and in the absence of those, to customary names. Variations in-country laws and the legal status of names with "meaty" connotations can be confusing for businesses that cater to the vegetarian/vegan market. For example, France banned 'meaty' names for plant-based imitations, and for this reason companies have to rename their products. The question of whether words like schnitzel or wurst are attributed to animal origins will be decided on a case-by-case basis by national or EU-level courts, and court cases are on-going in various Member States.

1.6 Consumers' acceptance for vegan plant-based imitations

The future of plant meat analogs/imitations development relies on understanding consumer perception. Identifying consumers' motivators and demotivators are deemed necessary for designing meat imitations of the future [6].

Different demographic and lifestyle segmentation criteria have different levels of acceptance. In general, social and psychological factors are more important to understanding consumers' adoption of alternative proteins than demographic data. Consumers with high meat consumption rates are more open to cultured meat and meat substitutes that resemble meat, but they are less susceptible to plant-based meat substitutes, meat substitutes, plant-based meat substitutes, etc.

The majority of factors (personal, physical, environmental, or social environmental) that influence food choices are attitudes, food neophobia and disgust, familiarity, taste, and health. They also include social norms. Research typically shows that acceptability varies based on the source. The lowest is for insects, the highest the cultured meat. Alternative proteins made from plants are the most widely accepted [28] . Conventional eaters' attachment to meat is closely related to emotional connection and taste, while vegetarians or vegans are mainly motivated to avoid meat for ethical concerns (animal and human welfare). Flexitarians are an intermediary group motivated by health, environmental and ethical concerns resulting in meat consumption reduction. Besides health and environmental concerns, meat reduction can be reinforced by producing plant-based products similar to meat (aspect and taste).

Innovative foods are rejected and consumers prefer maintaining their usual dietary habits for emotional attachment or/and food neophobia (fear of eating new/unfamiliar foods) [28] [38].

1.7 Food Composition Databases

FCDBs and their main role

Food composition databases (FCDBs) are tools that provide in-depth details about the nutritional composition of foods, often from a specific country. They started to develop in the 19th century in a printed form but nowadays FCDBs are mostly electronically accessible. Data on food composition are crucial for many aspects of nutrition and dietetics, including determining a population's nutritional status, researching the links between diet and disease, prescribing therapeutic diets, nutritional interventions, and food industry processes like nutritional labeling and food reformulation. The standardization of food composition databases is one of the objectives of EuroFIR, a European alliance of organizations that gather data on food composition. Data on the nutritional content of foods is available in databases and tables of food composition. Typically, they include information on a variety of elements, such as energy, macronutrients, vitamins, and minerals. Additionally, certain FCDBs contain readings for specific vitamin or amino acid components (e.g. individual carotenoids, such as lycopene and lutein). Researchers are becoming more interested in collecting information not only from nutrient but also from non-nutrient bioactive molecules since many of them may have positive health benefits or, on the other hand, they may be.

Processed foods have lately been part of the nutrition habits. For example, in the Western diet, processed food can account for over 70% of total calorie consumption. The food business and related distribution systems have made it possible to have a steady supply of inexpensive food. That means that people are increasingly exposed to foods that are rich in salt, sugar, and saturated fat and energy-dense according to World Health Organization. The necessity to understand the nutritional variety of processed foods has led an international development for branded food composition databases, except from the current generic BFCDs, because they are unable to do that (BFCDs). BFCDs are essential for various governmental and non-governmental operations, such as research, evaluation of the state of the nation's health, and usage by ordinary people. Agricultural and Food policy decisions also need composition data. This information, which is provided by the BFCDS in order to improve public health, may be used to guide decisions on food reformulation, advertising, and labeling as well as to modify the nutrient composition of processed foods.

In 1982, Greece attempted to design a food database, but it has not been updated since 2004. The data bank, as it was originally known, under the name DAFNE (DAta Food NEtworking), was a first major effort to develop a database with the participation of fifteen European countries.

HelTH (Hellenic thesaurus of branded food composition data) is a dataset, created 2020 that collects information on the nutritional composition and quality from branded products on the Greek market [39]. HelTH summarizes the nutritional profile of foods, any health or nutrition claims mentioned on the package, and any other quality claims existing on the package (environmental claims, logos, origin, etc.). It is the first systematic attempt to build a Greek BFCD. The database is curated with information that is taken from food labels that were made available online by major retailer chains in Greece. The latest update was made about the allergens' file where it includes information about the presence or the absence of a possible allergen, the number of them or even a reliant claim [39-41].

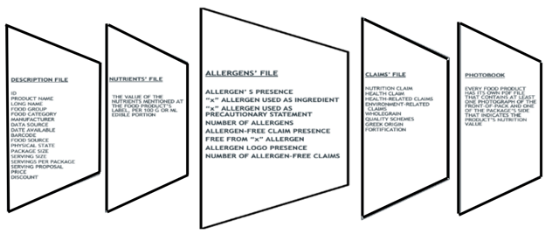

Figure 2 Main structure of HelTH Database

1.8 Front of pack nutritional labeling and Nutrient Profiling Systems

1.8.1 Nutrition Declaration and Front of pack labeling

Since December 2016, the Regulation requires the majority of prepackaged foods to carry a nutrition declaration, often provided on the back of the food package, in order for consumers to be informed and make healthy choices. The nutrition declaration is also referred to as a nutrition facts. The mandatory nutritional declaration must include the energy value, the amounts of fat, saturated, carbohydrates, sugars, proteins and salt, while it can be completed voluntarily with the indication of the amounts of monounsaturated and polyunsaturated fats, polyols, starch, dietary fiber , of vitamins and minerals. The declared values are average values based on: a) the analysis of the food by the manufacturer, b) a calculation based on the known or actual average values of the ingredients used, or c) a calculation based on generally defined and accepted data (EU 2011). In addition, the nutritional declaration can be supplemented by a repetition of its principal aspects in the primary field of vision of customers (known as "Front-of-Pack"). Other forms may be used for expression or presentation (e.g., graphics or symbols) on the front of the packaging (FOP) in addition to those included in the nutrition declaration, so long as they fit the standards outlined in the Regulation.

1.8.2 Nutrient profiling systems in Europe

Around the world, numerous different FOP nutrition labels have been created, and in Europe, many food producers and merchants have begun to apply these various FOP labels to their products. FOP nutrition labels are created in order to encourage the development of healthier products and to make it easier for customers to choose healthier food products. There are various NP systems different in components, reference units, method of qualifying, and other factors such as the purpose of existence or the obligation of usage.

There are currently validated nutrition labels in use in Europe, such as the so-called "Positive" labels (Swedish Keyhole Label, Slovenian Protective Food Symbol, and Finnish Heart Symbol) and the algorithm labels (British Multiple Traffic Light, French Nutri-Score), while Italy is developing its own system, the Nutrinform [42]. Three of these labels (the Keyhole Label, the Protective Food Symbol, and the Heart Symbol, also referred to as "Positive" or "Endorsement" FOPNLs, express a global evaluation of a product's healthiness using a positive or a negative threshold. Products that are system-healthy in terms of total fats, saturated fats, colors, carbs, sugar, fiber, and salt receive the distinctive emblem. However, Keyhole and Heart symbol criteria include whole grain grains and trans fatty acids, which are not mandatory labelled. Another applicable example in Europe is Multiple Traffic Light. Multiple Traffic Light uses marking alerts to customers for a product's excessive calories, total saturated fat, and salt content. It expresses a single qualitative judgment on the food, which receives a color code: A/dark green, highly recommended, B/light green, C/yellow, middle range, D/orange, E/red, least healthy, such as sweets or fatty snacks. Nutri-Score, encourages healthier food formulations and helps customers make better choices ranking foods from "best nutritious quality" to "least good nutritional quality" in five boxes with letters, ranging from dark green to dark red. Nutri-Score and the Multiple Traffic Lights System have been indicated that communicate more effectively to consumers [42-43].

1.8.3 Nutri-Score

In May 2020, the European Commission, as part of its Farm to Fork Strategy, announced that a harmonized and obligatory front-of-pack nutrition label should be established for Europe by 2024. The FOP labeling program Nutri-Score is an optional profiling system whose major goals are to encourage product reformulation toward healthier product compositions and to assist customers in making better choices. In detail, it uses five boxes with letters to classify foods according to their overall nutritional quality, from A for items with the "highest nutritional quality" to E for those with the "least good nutritional quality," ranging from dark green to dark red, respectively. First, a total score (FSAm-NPS score) is determined, ranging from -15 to +40, with two dimensions: positive points (0–10) are given to components that are disqualified, such as salt or SFA, and negative points (0–5) are given to each component that is qualified, such as protein or fiber per 100 g/mL of each product (food/beverage). The FSAmNPS is a modified version of the original British Food Standards Agency nutritional profiling system (FSA-NPS). The Nutri-Score is based on one set of criteria for all pre-packaged foods with mandatory nutritional declaration in accordance with Regulation (E.U.) No. 1169/2011 but has some adaptations on food categories such as beverages, cheeses and added fats. Label is modeled on the energy efficiency labels applied. NS can increase participants' capacity to rank food goods according to their nutritional content, and the negative scores D and E may lower impulsivity to purchase unhealthy foods (Figure 3). Facilitating the comparison of food products within the same category may encourage food reformulation.

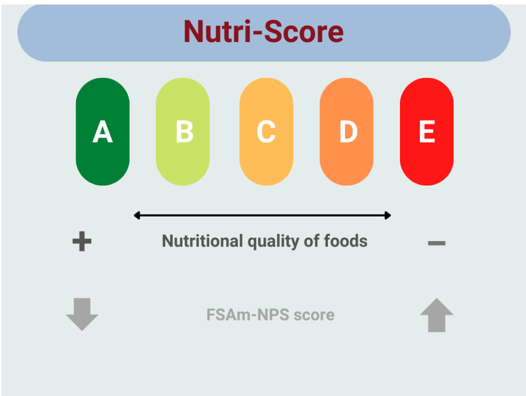

Figure 3 Nutriscore based on FSAm-NPS score

Aim of the study

The purpose of this study is to describe meat and dairy substitutes in terms of their content, including ingredients, nutrition, environmental claims, quality indicators, and their nutritional composition, both collectively and according to the alternative protein source that is the primary component of each product. The main aim is to compare these products' nutritional profiles in between the different categories that result but also to those of their counterparts that are based on animal products As part of a comparison of their nutritional composition with that of their counterparts, the food profiling system known as Nutri-Score is utilized to enrich the differences between the two in a way that is both straightforward and visually presented. The research also includes the development of a supplementary questionnaire- not the current study's top priority-but its purpose is to record the attitudes and impressions of Greek consumers to plant-based imitation products.

2. METHODOLOGY

2.1 HelTH Data Entry on Excel Sheets

HeLTH database is a FCBD (Branded Food Composition Database) and includes data of 4002 products, since 2020. The 1) description of the products, 2) the nutritional composition of foods 3) claims or quality indicators 4) allergen existence and 5) photobook are the main five files included in the database. The food data information and categorization is based on Langual and EuroFIR food description and classification system and the data is recorded to Excel spreadsheets.

2.1.1 Data source

The data collection derives from the package of each individual product. This includes the front-of-packaging labeling (FOPL), the back-of-package labeling with all of the nutritional information, as well as any other side of the box that has information that was provided by the manufacturer. Product data, including those that refer to claims (health, nutrition, environmental, Greek origin, fortification, etc.), and/or to the exact nutritional content of the product, are utilized in this process. In some circumstances there are missing data on the package, which is usual not obligatory to the nutritional declaration. This is represented as a "0" zero value on the excel file. Furthermore, when a nutrient is listed as "trace," this information is likewise recorded on the sheet page of the database as a "0" value; however, when " < value "is listed, the exact number of the value is shown as the limit content.

2.1.2 Data collection

HelTH's data source was firstly form "AB VASILOPOULOS" e-shop that made the procedure of the data collection constrained and more often did not represent the overall market trend. For this reason, a total of 13 internet retailers were included on the list that was developed. This list included not only the most popular large supermarkets on the Greek market, but also some smaller retailers that specialized in organic, and/or deli products. This was done in order to have a holistic approach to the total market, since many meat and dairy imitations are considered to be limited or niche products. Two of the big supermarket chains are representing the 50% of the total Greek market and the other 11 are either smaller supermarket chains or supplementarily specialized in vegan/organic/deli products. The first attempt of the whole data collection per product was from a single retailer but, due to the fact that not all the retailers have photos from the entirely product package available, a crossing collection method was used. This is a new entry on the methodology of HelTH in order to collect as many data as possible. This means that information of each side of package may be from different retailers or that some information comes from retailers' inputs in the websites. For both cases mentioned, verification at least in three different shops was obtained to ensure that there is no mistakes from the retailers inputs. To guarantee that all accessible items were recorded, a search was undertaken on the selected supermarkets' websites using keywords such as "meat alternatives", "meat replacements", "meat-free", "dairy alternatives", "dairy substitutions", "dairy-free", "plant-based", "vegan", and "vegetarian".

2.1.3 Data exclusion

During the data entry process, products only considered and listed that were being sold as imitations. The rejection of plant-based dairy products such as vegetable creams and plant-based ice creams was excluded from the analyses on the fact that neither them nor their animal counterparts are diet protein carriers. In addition, vegetarian food such as falafel, semi-prepared meals like dried soy mice, mixtures for preparation and other plant-based food that do not mimic a specific animal-based counterpart were also excluded. Fish imitation and egg imitations were represented only by one product per category (n=1), thus they were excluded for the purpose of the study. Products without clear images or without any photograph on websites are further refused. Most of the time, various retailers give the same product different names. Consequently, the removal of duplicates was also a high-priority methodology step. As previously stated, the final exclusion criterion was if a product's information could not be validated by at least three retailers.

2.1.4 Data expansion

In June 2022, the database contained data for only n=49 plant-based meat and dairy imitations. Dairy imitation included seven cheese imitations and eight yogurt imitation and most of them were milk imitations. They were no meat imitations when the data entry was started. The procedure of the data entry took place from July 2022 to November 2022 and it was conducted manually following the instructions of Helth's MANUAL (see appendix). Depending on which animal-based counterpart the plant-based imitations mimic, a categorization was established to describe each of the new plant-based categories, in accordance with HelTH's description and classification system

(Langual and EuroFIR). The new meat and dairy imitation categories are described below on Table 4. For further information entry, some new describing factors are described in the results, as part of the expansion procedure [44].

Table 4 Presentation of food included in each meat and dairy imitation category eligible for the 2022 HelTH expansion.

Imitation Categories	Description
Cold cuts	Meat-free products appearing to mimic cold cuts, including "salami", "turkey", "ham", "bacon", "chorizo", "kebab cold cut", "carpaccio".
Sausages	Meat-free products appearing to mimic sausages, including deep frozen sausages and cold cut sausages. Features either "sausage", or "hot dog", in the product name
Red meat	Meat-free products appearing to mimic red meat products, including "burgers", "meatballs", "mince", "kebab", "steak", "souvlaki", "gyros".
Poultry meat	Meat-free products appearing to mimic red poultry products, including "nuggets", "schnitzel", "Gordon blue", "chicken burger", "chicken chunks".
Milk	Dairy-free products appearing to mimic milk, including soy, almond, coconut, etc., beverages, either flavored or unflavored.
Yogurt	Dairy-free products appearing to mimic yogurt, including "yogurt", "yogurt dessert".
Cheese	Dairy-free products appearing to mimic cheese, including "white cheese", "spread cheese", "yellow cheese slices", "yellow cheese grated", "yellow cheese block".

2.2 Nutritional composition and profiles

The Nutri-Score nutrient profiling system, macronutrient composition, nutrition claims, and package quality characteristics were examined for all products. Each product's nutritional declaration per 100 g or 100 mL, ingredients, health and nutrition claims, trademarks, and endorsements were transcribed from photographs.

The Nutri-Score algorithm was calculated for each food based on its nutritional composition per 100 g of food. In detail the content of energy (kJ), total sugars (g), saturated fatty acids (SFAs) (g), and sodium (mg) (negative nutrients) is scored from 0 to 10 with higher scores for higher content and the content of protein (g), fiber (g), and Fruits/Vegetables/Pulses/Nuts/specific Oils content (FVPNO%) (positive nutrients) is scored from 0 to 5 with higher scores for higher content, as well (Figure 4) [45].

The Individual Nutrient score values are added together to determine the overall FSAm-NPS Score, which ranges from -15 to +40 and is derived by subtracting the positive from the negative nutrients scores. For the purpose of calculating the FSAm-NPS score, all foods are eligible for fiber and FVPNO scores. The protein score is only considered in the calculation if the sum of negative nutrition point scores is less than 11, if a food's FVPNO score is equal to 5, or when calculating the FSAm-NPS Score for cheeses.. In other cases of negative points are <11 protein content is not taken into account in the calculation of the nutritional score.

The FSAm-NPS score is subsequently converted to Nutri-Score grades according to the following basic criteria: A was allocated to foods with a score between 15 and 1, B to those with a score between 0 and 2, C to those with a score between 3 and 10, D to those from 11 to 18, and E to those from 19 to 40.

A two-step procedure was used to arrive at an estimate of the FVNPO% based on the constituent list. In the first step of the process, each and every food was analyzed to determine whether or not it had the required minimum percentage of fruits, vegetables, pulses, nuts, and oils made from rapeseed, walnuts, and olives. This percentage is forty percent. After that, a detailed quantification was performed on the items that were considered to have met this minimum requirement. In order to accomplish the goals of this investigation, the Nutri-Score algorithm's parameters were taken into consideration. The ingredient list of plant-based imitations usually typically include components like vegetables, nuts, fruits, legumes, and oils.

However, prior to awarding positive points for the FVNPO percentage of the food, it is necessary to take into consideration both the processing method and the form of the end product of the FVNPO. For instance, particular requirements have been set for the estimation of coconut, which was considered a fruit only when it was present in the form of fresh coconut. In addition, fruit juice concentrates, protein powders, candied fruit, and fruit flours were not taken into consideration as FVNPOs. According to the instructions provided in the Nutri-Score algorithm, beverages made from plant-based ingredients are counted as "solid foods" at the score calculation [11][46,47].

Products that lacked information about energy, saturated fat, total sugar, and sodium were rejected because no Nutri-Score could be determined. Possible causes of missing nutrient values include a lack of nutritional statement or low-quality photos of the individual foods. For "positive nutrients," however, missing information was assumed to be zero.

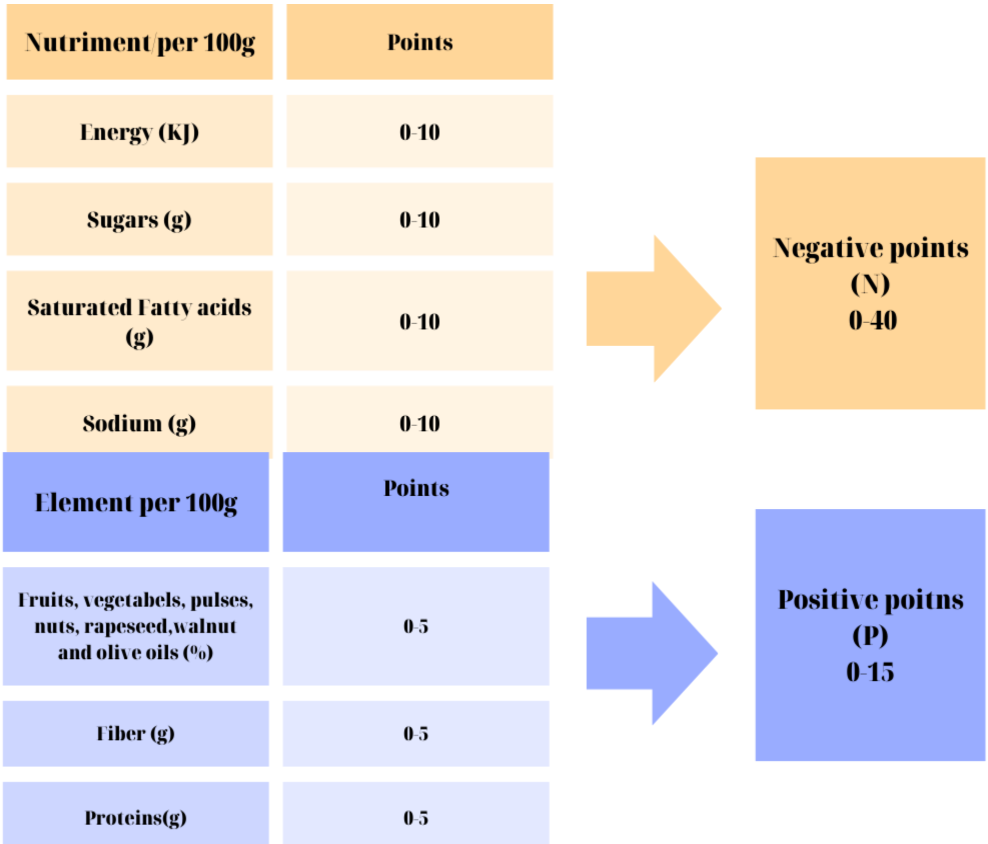

Figure 4 Graph on how Positive (P) and Negative (N) points are calculated during NutriScore algorithm. For beverages the point range 0 to 5 is adapted to 0 to 10

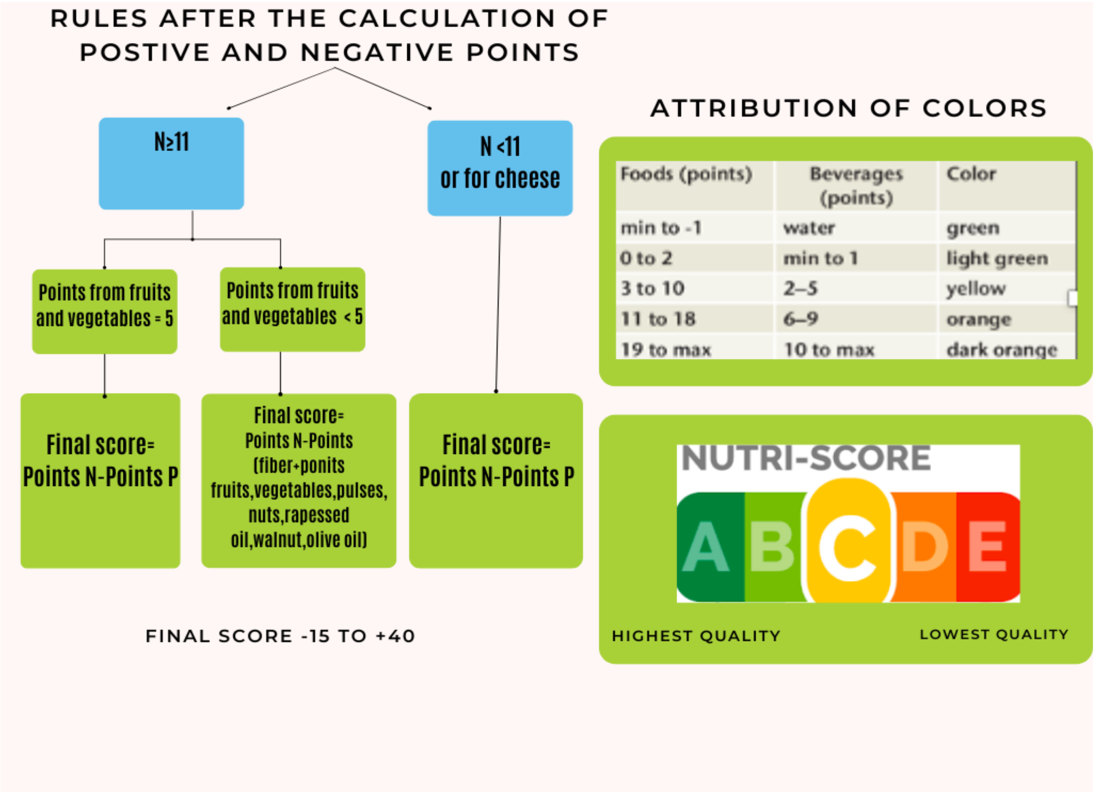

Figure 5 Final FSAm-NPS score calculation method and the attribution of Nutri-Sore colors.

2.3 Statistical analysis

The software IBM SPSS Statistics® was used to conduct the statistical analysis (version 23, Northridge, CA, USA). Both the data on the nutritional composition of the food (content per 100 g or 100 mL of product) and the FSAm-NPS score were examined as continuous variables. The Kolmogorov–Smirnov test was used to determine whether or not the data were normally distributed. The normal distribution was not followed by any of the variables at all. Consequently, the values of the variables were expressed using the median (interquartile range). The Kruskal–Wallis test for non-parametric comparisons between k separate samples was utilized to look for differences. In order to determine whether or not there were differences, the Kruskal–Wallis test, which is used for making non-parametric comparisons between k different samples, was applied. Statistical significance was set at 0.01% to adjust for multiple comparisons (Bonferroni correction).

3. RESULTS:

3.1 Recording imitation products

As mentioned before, only 49 plant-based meat and dairy imitations were in the database in June 2022 (thirty four milk imitations, seven cheese imitations and eight yogurt imitations and no meat imitations). From July to November 2022, new data entry was conducted manually from the online stores (Table 5). A total n=534 plant-based products were seen and recorded in the online stores. Duplicates (n=49) were excluded after revision of them and remarking the barcodes of same products with similar product names and then the total amount was decreased at 485. In the need of the study, concerning alternative sources of protein, including imitates only, n=9 semi-prepared products, n=5 mixtures, n=1 fish imitations, 1 egg imitation, 24 plant-based ice creams, 15 plant-based creams and 6 plant-based powders were excluded. This resulted in 421 products for analysis (Figure 7), which included a variety of meat and dairy imitations (Figure 6).

Table 5 Online shops used for the analyses and the first total amount of the products

Online retailers (n=13)
www.ab.gr
www.sklavenitis.gr
www.biologikoxorio.gr
www.chalkiadakis.gr
www.e-fresh.gr
www.kritikos-sm.gr
www.market-in.gr
www.bazaar-online.gr
www.e-shop.masoutis.gr
www.thanopoulos.gr
www.greenhousebio.gr
www.bio2go.gr
www.4seasons.bio

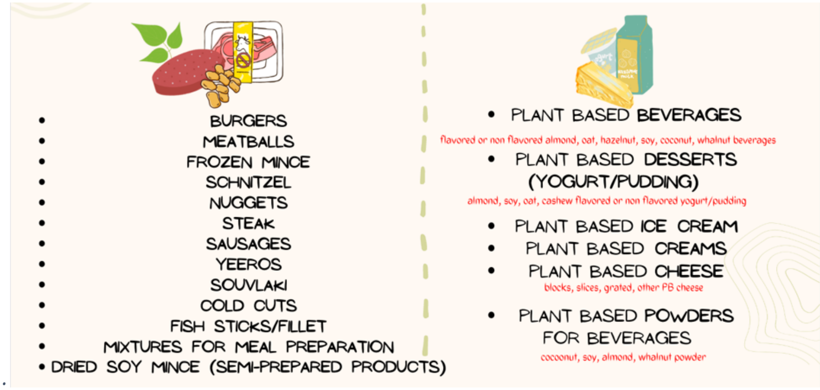

Figure 6 Different kinds of plant-based meat (left) and dairy (right) observed via internet searching.

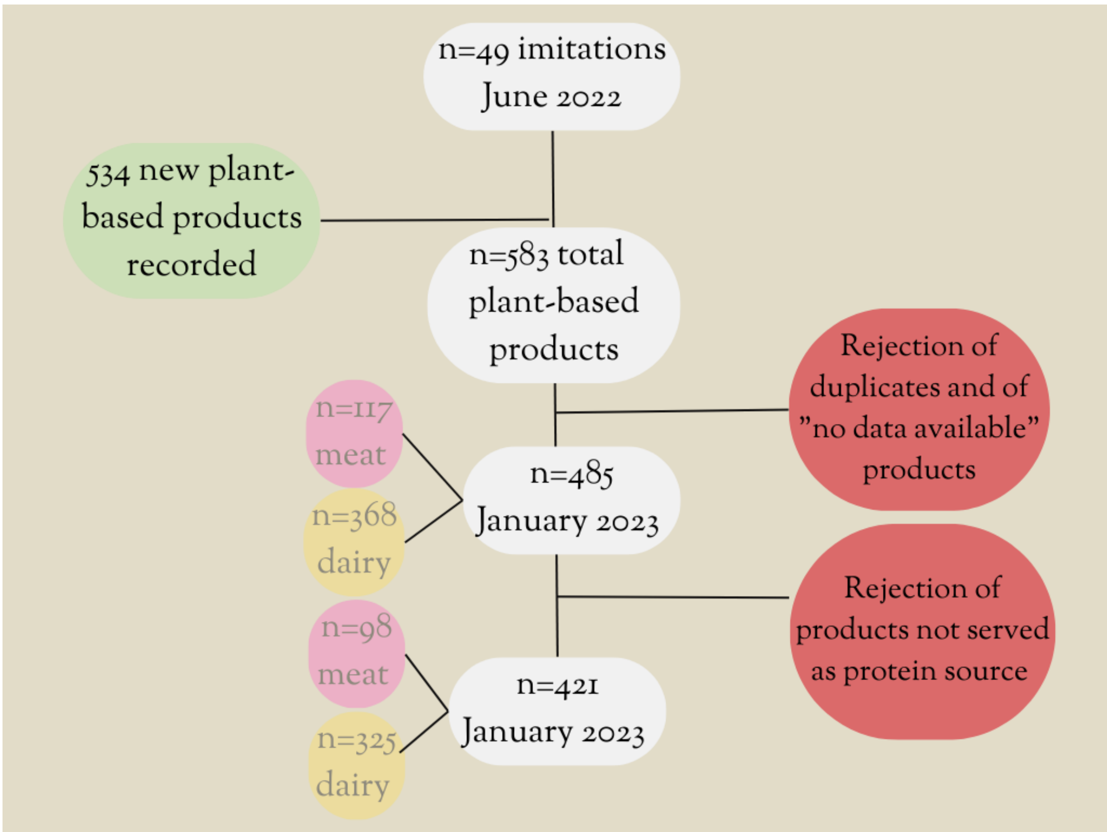

Figure 7 Flow chart of the targeted expansion of HelTH database with plant-based products.

After the collection of overall data a classification of the different observed categories a categorization and an inclusion of the different kind of products was necessary.

This new classification had to be done according to HelTH's manual (EuroFIR and Langual prescriptions) including new additions from Foodex 2. The main food categories of HelTH are listed below (Table 6):

Table 6 Food categories based on HelTH database

1.Milk, milk products, milk substitutes	8. Vegetables or vegetable products
2. Egg or egg products	9. Fruit or fruit products
3. Meat or meat products	10. Sugar or sugar products
4. Seafood or similar products	11. Beverages (Non-milk)
5. Fats or oils	12. Miscellaneous food products
6. Grains or grain products	13. Meals for special nutritional use
7. Nuts, seeds or products	

The expansion occurred within food categories "1" (milk, milk products or milk substitutes) and category "3" (meat, meat products, meat analogs). Inside the meat food category, there are 7 food subcategories with the last being the "meat analogs" (See appendix). The term "analog" was renamed to "imitation". The groups for the food subcategory had to be generated according to those for existing counterparts. So, five food groups were done and each of them included their food subgroup categories according to the different characteristics of the product (Table 7). For dairy imitations the methodology followed was the same. On the other hand, inside food category "1" where milk, milk products, and substitutes are involved, there is the food subcategory "4" for imitation milk products. There were 5 new food groups generated as well, including plant-based imitation milk (beverages), plant-based yogurt/ yogurt deserts, plant-based cheese, plant-based ice cream, and any other plant-based cream (i.e heavy cream). Each food group included at least 2 food subgroups defining the exact characteristics of the dairy imitation products. More details on which exact products are included are shown in Table 8.

Table 7 Meat imitation classification (Food category 3)

Food subcategory 7	Food group	Food subgroup
Meat imitations	1.Preserved meat/ Cold cuts imitations	1. salami 2. turkey 3. ham 4. bacon 5. chorizo 6. kebab cold cut 7. carpazzio
	2.Sausages imitations	1. deep frozen sausages 2. cold cut sausages
	3.Red meat imitations	1. burger/medallions 2. meatballs 3. mince 4. kebab 5. steak 6. souvlaki 7. yeeros/gyros
	4.Poultry imitation	1. nuggets 2. schnitzel 3. gordon bleu 4. chicken burger 5. chicken chungs
	5.Other meat imitation	1. Tempeh served as meat 2. Any other kind

Table 8 Dairy imitation classification (Food category 1)

Food subcategory 4	Food group	Food subgroup
Milk imitations	1.Plant-based beverages	1. Flavored 2. Non flavored
	2.Plant-based yogurt/yogurt desert	1. Yogurt imitation/Yogurt dessert imitation 2. Pudding
	3.Plant-based cheese	1.White cheese/Feta 2.Yellow cheese 3.Cream/Spread cheese
	4.Plant-based ice cream	
	5.Plant-based creams	1. Whipped cream 2. Cream

3.2 Helth update

Due to the fact that plant-based products are a new entry in the database issues during the categorization and the data entry occurred. For example meat imitations had many plant-based origins such as soy, pulses, cereals. This resulted in classification products with identical shapes and resembling counterparts, but with different origin sources of protein, which could result in distinct nutritional properties. As already referred, except from processed meat there were semi-prepared products like dried soy or mixtures of the above ingredients. For dairy imitations case, cheeses not only appeared as white, yellow or spread but also had different origin ingredients and different forms (slices, block, or grated). Hence, the classification was a challenge in order to include as many possible products without missing any due to the multiple facets of a product. For that reason, it was necessary to add new facet factors for describing in detail plant-based food that were not already existed in HeTH's manual. This approach is more inclusive and encourages the update of HelTH whenever a new innovative product is introduced.

3.2.1 New product long name including source on product long name

A product's long name is a short description of the product divided by commas ",", including the name with the main characteristics, the food group, and the flavor ended by the package size. Most of the imitation products due to their special characteristics could not be uploaded in a manner already existing. The product long name methodology, for this new innovative food category, had to be reformulated and updated, without deviating from the existing manual of HelTH, ensuring that all new information (vegan claims, organic claims, specific imitated counterpart, origin, and basic ingredient) would be mentioned and the new plant-based products would be distinguished from their counterparts. Indicatively, there were 6 criteria for the production of meat imitations long name (Figure 8). For the creation of the long name, it was crucial that specific imitated food would be mentioned. To accomplish this, the first step was to record the product food subcategory (meat imitation or dairy milk imitation) (Figure 8), followed by the exact counterpart mimic product (food group), the plant origin and the main ingredient to help being identified from potential future new imitations (cultured meat/insect-based, etc.). Then, specific product characteristics (i.e vegan and/or high protein and/or sugar-free), labeled on FOP, are mentioned, before the brand and the size of the product.

Figure 8 Demonstration of the creation of product long name for meat (up) and dairy (down) imitations.

3.2.2 New iD code

The id encoding is an 8-digit method that simplifies the organization of HeLTH and the identification of its products. Based on Greek data, this methodology has been adopted by EuroFIR's Language Categorization and permits the most accurate food classification. The first two digits refer to the food's category, the third to its subcategory, the fourth to the group to which the food belongs, the fifth to its subgroup, and the sixth refers to the exact product. If a food product description does not match a number, "0" is used. In the absence of further categorization, "0" should be used again to complete these digits to always get an 8-digit id. Specifically for the meat imitations the iD number follows this pattern: 3 (food category) / 7 (food subcategory) / 1-5 (food group) / 1-7 (food subgroup, depending on group) and 4 more digits for product number from 0001 and on. For dairy imitations the iD code follows the same pattern.

3.2.4 New added factor for basic ingredient which represents the main protein source.

Classification systems have been created for different purposes and reflect different legislations. Langual™ is an international multilingual faceted thesaurus, language-independent, suitable for use in numerical databases [48]. Facet descriptors are further information that can be added to or included along with the base terms.

Table 9 Main Langual facets based on different products' characteristics. (Modified from EuroFIR Food Forum 2015-Ireland J & Møller A-Official presentation LanguaL™)

Characteristic	Facet
FOOD GROUP	**Product Type** Derived from a combination of consumer, functional, production, and legal characteristics. Contains the Codex Alimentarius Classification for Food and Feeds and additional Codex classifications.
FOOD ORIGIN	**Food Source** Plant or animal species, or chemical food source **Part of Plant or Animal**
PHYSICAL ATTRIBUTES	**Physical State, Shape or Form** Example: liquid, semiliquid, solid, natural shape in its entirety, fragmented
PROCESSING	**Extent of Heat Treatment** **Cooking method** Cooking technique dry or moist heat cooking; cooking with fat; microwave cooking.

	Treatment Applied Additional processing processes, including the addition, replacement, or removal of components **Preservation Method** Primary technique of preservation
PACKAGING	**Packing** **Medium** **Container or Wrapping** Container material, shape, and perhaps additional features **Food Contact** The surface(s) with which the food is in contact
DIETARY USES	**Consumer Group/Dietary use** Human or animal; special dietary characteristics
GEOGRAPHIC ORIGIN	**Geographic Places and Regions** ISO-code (ISO 3166) for country of origin, local codes for region
MISCELLANEOUS CHARACTERISTICS	**Adjunct Characteristics of Food** Additional miscellaneous descriptors

FoodEx2 is a comprehensive food classification and description system for data collection in several food safety domains made by EFSA. FoodEx2 was evaluated and altered to accommodate the needs of the various users. Specifically, the language of the terminology was significantly expanded in the sections on raw materials and natural sources, new hierarchies were added, and the relationship between the terms and the most important factors was simplified. Now contains 32 facets that provide several alternatives for describing a specific feature of a food group, such as treatments received, production method, ingredient, or part-nature [49]. Latest version of Langual 2017 was updated extensively-especially in the area of facets product type" and food source", yet the domain of "ingredient" of FoodEx 2 was not incuded (Table 9). In order to include this aspect to HelTH for the subsequent analyses, the first five elements and their respective percentages of the ingredient list were recorded to aid in classification and statistical comparisons across different categories. The new data cell for main ingredient was created in the excel datasheet.

C		AB
New_long_name		INGREDIENT
Meat analogue, plant based, meatballs, vegan, Vivera, 200g	3	SOY AND WHEAT
Meat imitation, plant based, burger, vegan, Vegafit, 150g	2	WHEAT/SEITAN
Meat imitation, plant based, kebab, vegan, Genius, 300g	1	SOY/TOFU
Meat imitation, plant based, kebab, seitan, vegan, organic, Vegg	2	WHEAT/SEITAN
Meat imitation, plant based, mince, from seitan, vegan, organic,	2	WHEAT/SEITAN
Meat imitation, plant based, mince, vegan, Beyond meat, 300g	3	PEA PROTEIN
Meat imitation, plant based, mince, high protein, vegan, Moving r	3	PEA PROTEIN

Figure 9 Facet of "ingredient" in the datasheet of HelTH/

3.2.5 New cells for claims file such as meat-free /logo, palm-oil free

Some new logos except from common vegan logo appeared in a big percentage for stating that a product is for example not animal-based or to state the absence of non-nutritive and unsustainable ingredients i.e palm oil, so for this case there was a need to add them as a new facet-cells on the data recording.

C	CK	CL
New_long_name	Meat-free	logo
Meat analogue, plant based, meatballs, vegan, Vivera, 200g	1	
Meat imitation, plant based, burger, vegan, Vegafit, 150g	1	1
Meat imitation, plant based, kebab, vegan, Genius, 300g	1	1
Meat imitation, plant based, kebab, seitan, vegan, organic, Vegg	1	1
Meat imitation, plant based, mince, from seitan, vegan, organic,	1	1
Meat imitation, plant based, mince, vegan, Beyond meat, 300g		
Meat imitation, plant based, mince, high protein, vegan, Moving r		1

C	FZ	GA
New_long_name	Palm oil free	logo
Meat imitation, plant based, burger, vegan, Vegafit, 150g		
Meat imitation, plant based, burger, vegan, gluten free, Meatoff,	1	1
Meat imitation, plant based, burger, soy, organic, Fior di loto, 20		
Meat imitation, plant based, burger, vegan, organic, Veggyness,		
Meat imitation, plant based, medaillons, vegan, organic, Veggyn	1	
Meat immitation, plant based, burger, from quinoa pulses and su	1	

Figure 10 Addition of new cells in the datasheet of Helth. Meat-free and Palm-oil free cells.

3.3 Main ingredients on categories - Products description

All imitations are plant-based, although the main ingredient differ among categories and subcategories. Main ingredient bases that occurred in meat imitations are soy / tofu , wheat / seitan/ wheat gluten, and other mixed matrix that may include the combination of the previous two ingredients or any other matrix (Table 10). Meat imitation products are based mostly on wheat, or other ingredients followed by soy (Figure 10).

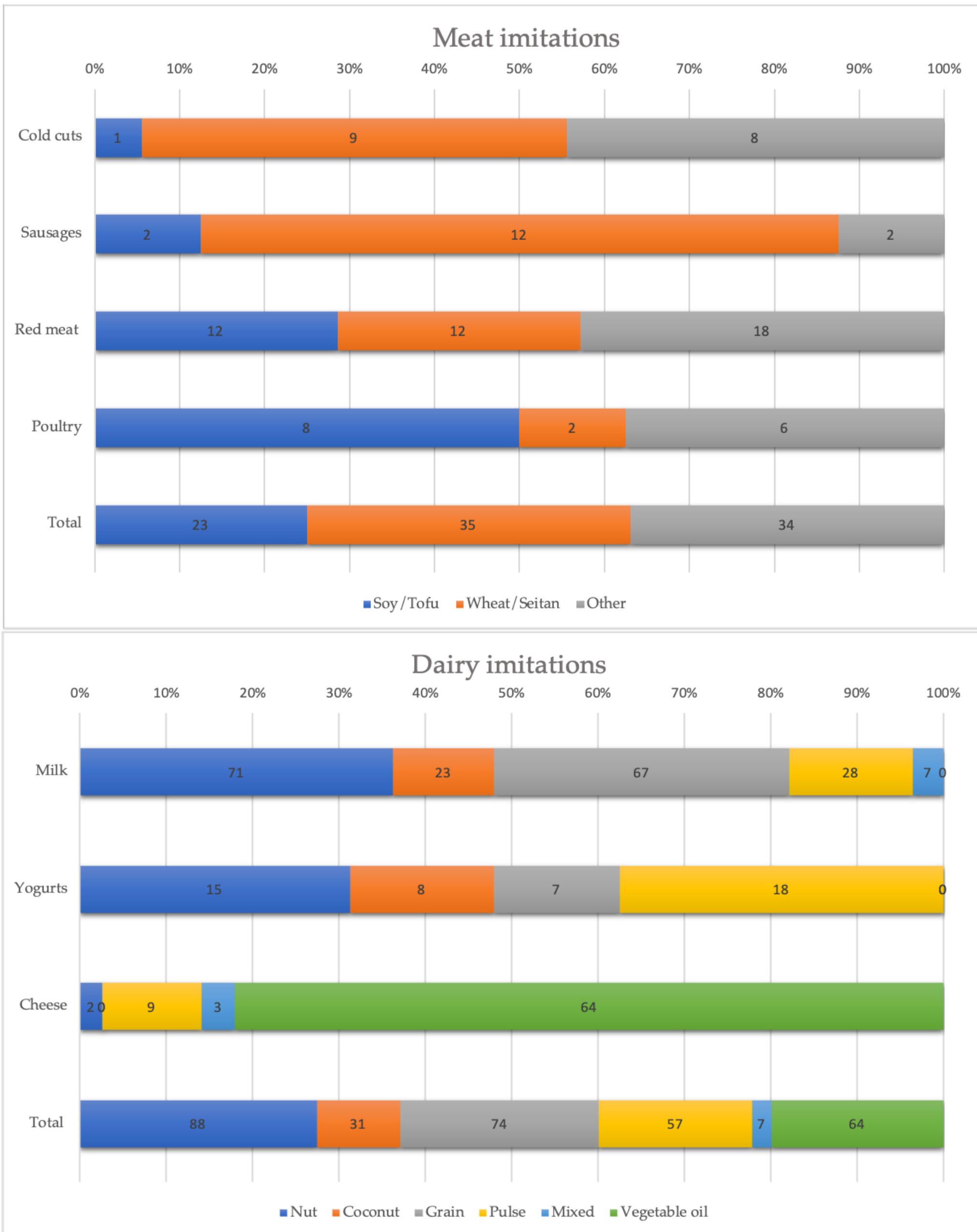

Figure 11 Percentage on products that include protein-containing ingredients for imitation meat and dairy alternatives.

Among the several food subgroups, only sausage imitations can be distinguished by their primary constituent, which was predominantly wheat. For sausages, cold cuts, and red meat majority of formulations have wheat (50%, 75% respectively), followed by other ingredient recipes (44%, 13%% respectively), and lastly from soy matrix (6%, 13%). Soy (50%) is the first main ingredient for poultry imitation, though, mixed ingredients (38%) and wheat (13%) follow. In Summary, mixed (37%) and wheat (37%) bases are mostly used in meat imitation products that mimic red or preserved meat rather than soy (26%). Even so, after assessing the total products, none of the percentages of distinct ingredient formulations appear to have predominated (x^2 test: p-value = 0.055 *(p = 0.0001)*).

Table 10 Ingredients that were dominated in category other for meat imitation products.

Meat imitation category "other: ingredients	Number of products (n=33)
Soy & Wheat	15
Pea protein & Fava beans	2
Pea & Rice	4
Pea & Potato starch	2
Pea & Mushroom	2
Wheat & Chickepeas	2
Soy & Pea & Vegetables	2
Quinoa & Pea & Beans	1
Spinach & Sunflower seeds	1
Chickpeas & Rice	1
Vegetable mix powder & Vegetable oils	1

Dairy imitations on general were based on nuts (36%), followed by grains (34%), vegetable oil (20%), pulses (15.418%) coconut (11%) and mixed matrix (3%) (Figure 10). The mixed matrix was mostly coconut with rice, multigrain, seeds and nuts or pea and rice. In particular milk imitation products were based on nuts (almond, walnut, cashew, hazelnut) (36%), followed by those based on grains (rice, oat, quinoa) (34%), coconut (12%), pulses/legumes (soy, peas) (14%) and another or a mixed matrix (4%). Yogurt imitation products were based on pulses (38%), nuts (31%), coconut (17%), and grains (15%). Yogurt imitations appear as fermented products of either soya juice or other nut (almond drink), fruit (coconut) product. Lactobacillus Bifidus and Acidofillus usually used for the fermentation while modified starch of tapioca or corn was used as supplementary ingredients with other thickening agents (guar gum and/ or pectin). Cheese imitation products were mainly based on vegetable oils (83.1%) followed by pulses (12%), mixed (4%) and nuts (3%).

Cheese imitations in detail appeared in three forms (white (10%), yellow (77%), and spread cheese (13%)) (Figure 13). White cheese was dominantly feta cheese imitation (100%) spread cheese that appeared with or without added flavor, while yellow cheese was 12% grated, 47% sliced and 42% in a block form. A typical matrix of vegetable oil cheese included water, vegetable oils (coconut oil, extra virgin olive oil, sunflower oil), -most of the cases was coconut oil- modified starch, starch (from potato most usually) and sea salt, while tofu cheeses were made from tofu (soybeans up to 55%, water, coagulating agents: magnesium chloride, Calcium sulfate), vegetable broth (sea salt, yeast extract, sunflower oil, vegetables i.e. leek, carrots, celery, mace, nutmeg, parsley), lemon juice concentrate or other congelation agents: magnesium chloride, calcium sulfate). Lastly, nut-based cheese appeared with a cashew matrix (up to 70%), live vegan cultures, flavorings, and/or colorants (Figure 14).

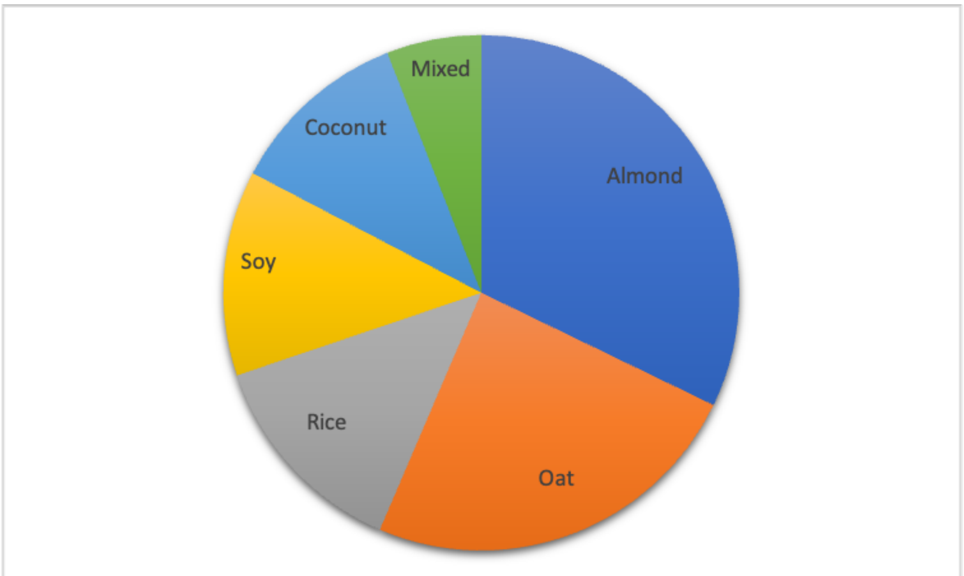

Figure 12 Milk imitations pie chart with most appeared ingredients (Almond 32%, Oat 24%, Soy 13%, Rice 13%, Coconut 12%, Mixed 6%)

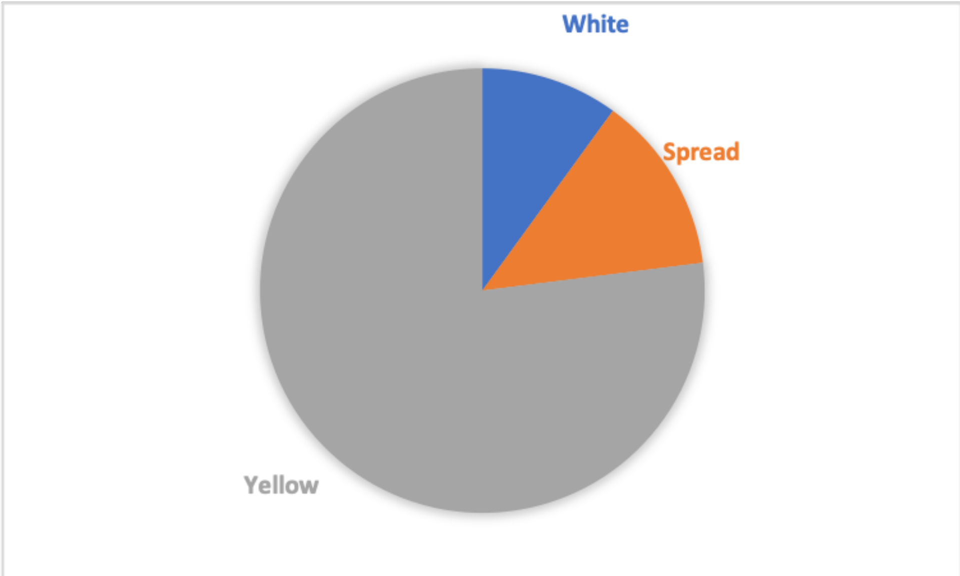

Figure 13 Cheese imitations pie chart with specific categories appeared (Yellow 77%, Spread 13%, White cheese 10%)

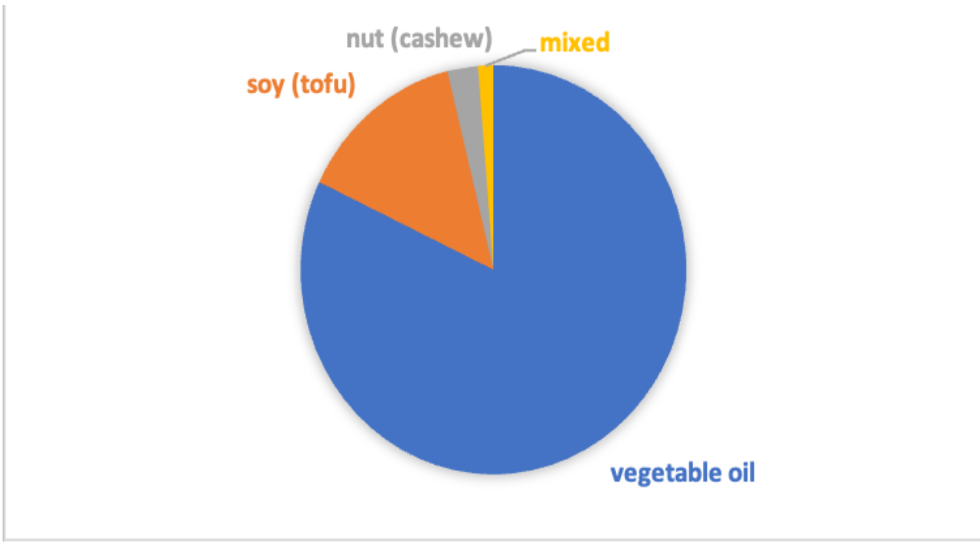

Figure 14 Cheese imitations pie chart with the percentages of different ingredients on the total cheese imitations matrix. (Vegetable oil 83.1%), pulse/soy/tofu 12%, mixed 4% and nuts 3%

3.4 Claims and quality indicators on plant-based imitations

Both meat and dairy imitations on the Greek market appeared with on-pack communication labeling. The majority of meat and dairy imitations had a variety of claims, including nutrition claims (65%), special diet-vegan (62.3%), allergen-free (39.6%), naturalness (25.2%), and bio/organic (37.3%). Nevertheless, none of the investigated products, though, contained a health claim (Table 11).

Table 11 Prevalence of meat and dairy imitation products bearing nutrition claims and other quality indicators on their packaging.

Imitation products	Protein Claim n(%)	Sugar Claim n(%)	Fat Claim n(%)	Fiber Claim n(%)	Vitamin Claim n(%)	Minerals Claim n(%)	Vegan/ Vegetarian n(%)	Meat-free n(%)	Dairy-free n(%)	Gluten-free n(%)	Soy-free n(%)	Bio/ Organic n(%)	Natural n(%)
Cold Cuts (n=18)	5 (27.8)			2 (11.1)	-	-	16 (88.9)	12 (66.7)	7 (38.9)	3 (16.7)	2(11.1)	15 (83.3)	2 (11.1)
Sausages (n=21)	8 (42.1)			2 (10.5)	-	-	18 (94.7)	15 (78.9)	8 (42.1)	4 (21.1)	1 (5.3)	13 (68.4)	2 (10.5)
Red meat (n=43)	16 (37.2)		4 (9.3)	8 (18.6)	5 (11.6)	5 (11.6)	31 (72.1)	21 (48.8)	5 (11.6)	10 (23.3)	8 (18.6)	10 (23.3)	12 (27.9)
Poultry (n=16)	11 (68.8)		2 (12.5)	6 (37.5)	4 (25)	4 (25)	14 (87.5)	10 (62.5)	2 (12.5)	2 (12.5)	2 (12.5)	-	3 (18.8)
Milk (n=233)	25 (10.4)	140 (58.1)	37 (15.4)	26 (10.8)	42 (17.4)	50 (20.7)	130 (53.9)	-	72 (29.9)	691 (28.60.5)	72 (2.90.9)	111 (46.1)	64 (26.6)
Yogurts (n=55)	9 (19.1)	10 (21.3)	5 (10.6)	-	7 (14.9)	7 (14.9)	23 (48.9)	23 (48.9)	10 (21.3)	21 (44.7)	13 (27.7)	12 (25.5)	11 (23.4)
Cheese (n=85)	-	-	-	-	-	-	60 (70.6)	60 (70.6)	62 (72.9)		46 (54.1)	14 (16.5)	24 (28.2)

Most often used nutrition claims for meat imitations were for protein (41.7%), fiber (18.8%), vitamins and minerals (9,4%). The category with the highest frequency of protein claims (68.8%), fiber claims (37.5%), and vitamin and mineral claims (25%) was poultry imitations (Table 11). On their package, 83.3% and 68.8% of cold cuts and sausages imitations were labeled as bio/organic. All categories of meat imitations contained natural claims, with the highest frequency (27.9%) observed in the red meat imitations.Most of them concerned the absence of preservatives and/or artificial ingredients (such as artificial vitamins). Concerning protein claims a quarter of the total products had the reference about plant based protein. There were also mentions such as "high content in plant-based protein", "x grams of plant protein per serving, "pure plant-protein (not concerned as a protein claim). Other ingredient mentions, in less than 10% of total products, referred to added ingredients such as "with extra virgin olive oil". Vitamin claims presented intertwined in B12 and for mineral claims in Fe only. As regards on environmental claims, GMO-free labels appeared too. It is remarkable also that only 3 products of the total were Greek with Greek mention on the package. Allegen-free claims were also found in all categories of meat imitations. There were gluten-free claims on 23.3% of red meat imitations, 21.1% of sausage imitations, 16.7% of cold cut imitations, and 12.2% of poultry imitations. There were soy-free claims on 11.1% of imitation cold cuts, 18.6% of imitation red meat, 12.5% of poultry imitations, and 5.9% of imitation sausage. Although, almost 90% of the total meat imitation products carried other allergens on the ingredient list such as nut or sesame or cereals. A vegan/vegetarian claim was present at 82.3% of the meat imitations, while 60.4% of these products carried a meat-free claim. Five of them carried a cruelty free mention and two were for other special diet one with a halal logo and one for keto diet.

In dairy imitation products, protein claims were present at 19.1% of yogurt imitations and 10.4% of milk imitations. The 58.1% of milk imitations had a sugar claim, 15.4% a fat claim, 10.8% a fiber claim, 17.4% a vitamin claim, and 20.0% a mineral claim. Thirty-seven percent of dairy imitations in general were bio/organic and twenty-six percent carried a natural claim ("100 % natural ingredients").

For milk imitations the most appeared nutritional claims concerned sugar (low sugar: 3%, sugar-free: 15%, with no added sugars/naturally occurring sugars: 40%) and fat claims (low fat claim: 12% and low-saturated fat claim: 3%, fat free claim: 0%). Products with vitamin claims usually carried more than one vitamin on it. Vitamin B12, B2, D2, E, were the most appeared combination , followed by the combination of vitamin D and K or D and B12 and D2. Mineral claims concerned only Ca (Calcium) and reached 20%. Milk imitations carried a Greek product mention reached 10%. Six milk imitation products carried an environmental claim with a logo about climate footprint

(CO_2 per kg). Cheese did not carried any nutritional claim while allergy-free claims concerned lactose and gluten. Forty-five percent of plant-based yogurts were gluten-free, while all dairy imitations categories carried a soy-free claim, in different percentages. The carried mostly sugar claims (49%-with no added sugars and 4% sugar-free claim). Nevertheless, 30% of imitation yogurts were Greek products. Summarily, the prevalence of dairy imitations that claimed to be vegan/vegetarian was 57.1%, while 38.6% claimed to be dairy-free (Table 11).

3.5 Nutritional composition, profile and comparisons

Nutritional composition based on mandatory nutritional labeling of meat and dairy products and their imitations is presented in Tables 12-15 and Figures 15-25.

3.5.1 Comparisons based the specific subcategory of imitation without concerning the main ingredient

In terms of calorie content, sausage imitations had the highest percentage (247kcal/100g) among all meat imitation products, followed by imitations of red meat (231kcal/100g), cold cuts (222kcal/100g), and poultry (220kcal/100g) (Table12). All meat imitations were both high in protein and fiber. Both sausage and poultry imitations were low in saturated fatty acids, however plant-based cold cuts were high in salt (Table 12). The highest concentration of carbohydrates was found in poultry imitations, although the sugar content of the various subcategories was quite similar, with the exception of sausage imitations. Related to plant-based dairy imitations, plant-based beverages were low in SFA, and yogurt imitations had a low total and saturated fat content

Table 12 Nutritional composition of meat and meat imitation categories

Meat Categories	Cold Cuts			Sausages			Red Meat			Poultry		
Nutrients	**Plant-based (n=18)**	**Animal-based (n=66)**	**p-value**	**Plant-based (n=19)**	**Animal-Based (n=27)**	**p-value**	**Plant-based (n=43)**	**Animal-Based (n=6)**	**p-value**	**Plant-based (n=16)**	**Animal-Based (n=14)**	**p-value**
Energy (kcal)	221.5 (180.0, 248.3)	169.5 (101.5, 273.0)	0.194	247.0 (211.0, 269.0)	247.0 (224.0, 300.5)	0.288	231.0 (195.0, 252.0)	213.0 (183.3, 234.3)	0.522	219.5 (190.3, 247.3)	194.0 (189.5, 230.5)	0.393
Protein (g)	27.3 (5.2, 32.2)	14.5 (12.7, 21.8)	0.055	25.2 (19.4, 30.6)	13.5 (12.2, 15.0)	**<0.001**	17.6 (14.9, 24.0)	12.9 (11.3, 18.5)	0.041	12.2 (9.4, 14.0)	16.4 (12.8, 18.4)	0.019
Fat (g)	12.2 (8.4, 16.0)	10.0 (2.3, 22.0)	0.322	12.5 (10.3, 15.0)	20.1 (15.5, 25.5)	**<0.001**	12.5 (7.6, 15.2)	15.6 (10.6, 17.0)	0.206	8.0 (7.3, 12.0)	9.6 (9.0, 11.9)	0.289
SFA (g)	1.8 (1.2, 3.6)	3.0 (0.8, 7.0)	0.479	1.3 (1.0, 7.4)	7.5 (5.5, 9.8)	**<0.001**	1.8 (0.9, 7.9)	6.7 (4.2, 8.2)	0.215	1.0 (0.7, 3.0)	3.7 (3.0, 4.2)	0.016
Carbo-hydrates (g)	5.4 (2.9, 6.5)	4.0 (1.2, 6.0)	0.134	4.2 (3.6, 5.6)	2.8 (1.0, 5.9)	0.04	7.0 (4.1, 10.5)	6.7 (2.0, 8.1)	0.488	15.9 (13.3, 20.0)	11.0 (58.0, 13.5)	**0.005**
Sugars (g)	1.7 (0.8, 2.4)	0.9 (0.0, 1.1)	**0.001**	0.6 (0.5, 2.0)	0.9 (0.48, 1.2)	0.956	1.1 (0.6, 2.0)	1.1 (0.8, -)	0.658	1.4 (0.6, 2.6)	0.6 (0.5, 1.2)	0.086
Fiber (g)	4.4 (4.1, 5.0)	0.0 (0.0, 0,0)	0.043	3.2 (0.7, 4.5)	1.5 (1.3, -)	0.456	4.1 (2.0, 5.7)	-	-	4.7 (2.3, 6.1)	3.7 (0.4, -)	0.354
Salt (g)	2.1 (1.8, 2.6)	2.5 (2.2, 2.8)	0.026	1.5 (1.3, 1.8)	2.3 (1.8, 2.5)	**<0.001**	1.3 (1.0, 1.8)	1.2 (1.2, 1.6)	0.811	1.3 (1.0, 1.6)	1.5 (1.3, 1.7)	0.271

Table 13 Nutritional composition of dairy and dairy imitation categories.

Dairy Categories	**Milk**			**Yogurt**			**Cheese**		
Nutrients	**Plant-based (n=221)**	**Animal-based (n=119)**	**p-value**	**Plant-based (n=40)**	**Animal-based (n=137)**	**p-value**	**Plant-based (n=80)**	**Animal-based (n=172)**	**p-value**
Energy (kcal)	46.0 (32.8, 57.0)	63.0 (46.0, 65.0)	**<.001**	80.0 (69.8, 97.5)	78.0 (69.0, 97.0)	0.034	283.0 (248.0, 305.0)	302.5 (247.0, 361.0)	0.034
Protein (g)	0.7 (0.5, 1.2)	3.3 (3.3, 3.5)	**<0.001**	2.1 (1.0, 3.8)	6.2 (4.8, 8.2)	**<0.001**	0.5 (0.0, 1.6)	23.0 (16.0, 26.0)	**<0.001**
Fat (g)	1.6 (1.2, 2.2)	1.6 (1.5, 3.5)	**0.001**	2.3 (1.9, 4.7)	2.0 (1.6, 4.4)	0.028	23.0 (20.0, 24.0)	24.0 (17.6, 29.0)	0.028
SFA (g)	0.2 (0.2, 0.4)	1.1 (0.8, 2.2)	**<0.001**	0.4 (0.3, 0.7)	1.3 (1.0, 2.7)	**0.001**	20.5 (15.8, 21.0)	16.0 (11.5, 20.0)	**0.001**
Carbs (g)	5.7 (2.5, 9.0)	4.7 (4.7, 5.1)	0.362	11.8 (5.6, 15.0)	5.2 (4.0, 8.7)	**<0.001**	21.0 (11.5, 23.0)	0.5 (0.0, 1.9)	**<0.001**
Sugars (g)	3.4 (1.3, 6.0)	4.7 (4.6, 5.1)	**<0.001**	8.5 (0.8, 11.0)	5.1 (4.0, 8.7)	**<0.001**	0.0 (0.0, 0.5)	0.3 (0.0, 1.0)	**<0.001**
Fiber (g)	0.6 (0.4, 1.1)	0.4 (0.0, -)	0.055	1.0 (0.5, 1.4)	0.0 (0.0, 0.8)	**<0.001**	1.9 (0.5, 2.9)	0.0 (0.0, 0.0)	**<0.001**
Salt (g)	0.1 (0.1, 0.1)	0.1 (0.1, 0.1)	0.301	0.1 (0.1, 0.1)	0.1 (0.1, 0.2)	0.359	1.9 (1.7, 2.1)	1.8 (1.4, 2.2)	0.359

3.5.2 Comparisons with counterparts

The study also compared the nutritional composition of plant-based meat and dairy imitations to their animal-based counterparts, per meat and dairy category, in terms of energy and important nutrients (protein, total fat, SFA, carbohydrates, sugars, fiber, and salt) (Table 12). (p=0.001) Plant-based cold cuts contained more sugars than their animal-based counterparts. Energy and key nutrients did not differ between plant-based and animal-based red meat imitations. Comparatively to poultry meat, imitation products had more carbohydrates than animal-based counterparts (p=0.005). The meat category with the biggest distinctions between plant-based and animal-based products was sausages. Specifically, sausage imitations contained more protein and less salt, total fat, and saturated fat than their animal-based counterparts. However, there were no significant differences in the amounts of energy-carbohydrates, sugar, and fiber..

But when related to dairy products (Table 13), there were observable differences across all categories Particularly, plant-based milk substitutes contained less calories, fat, SFA, and sugars, but also less protein. Similar levels of carbohydrates, fiber, and salt were observed. Compared to their animal-based counterparts, plant-based yogurt imitations were lower in saturated fatty acids and higher in fiber, but higher in carbohydrates, sugars, and lower in protein. Generally, plant-based cheese imitations had more saturated fatty acids, carbohydrates, and fiber, but less protein than animal-based cheese products. There were no differences between the energy, fat, and salt levels of yogurt and cheese imitations and their animal equivalents.

3.5.3 Ingredient-based and in between categories comparisons

Comparing meat imitations based on ingredients, without considering the exact subcategory they belong, (Figure 15) a big difference among protein content appears (Figure 16). In comparison to soy (14.5g/100g) and other/mix (15g/100g) based imitations, wheat-based imitations have almost 10 grams more protein (27g/100g. Energy (Figure 17) were very close in all of the three categories with 197 kcal for soy-based, 240 kcal for wheat based and 235 kcal on other/mix -based. Fiber content was higher on other/mixed products and salt approximately in the same level on each three categories with wheat-based to over 1,5 g per 100g (1,7g/100g) of product. Total and saturated fat are higher in other/mix -based (14,5g/100g and 3,5 g respectively), while carbohydrate content is much higher on soy-based but sugars on wheat-based. None of the above nutrients differences seemed to be significant.

When comparing the nutritional composition of meat imitations, in-between the meat categories, respectively, based on the main ingredients used to manufacture food products that mimic meat (Table 14), no differences were observed between soy-, wheat- or mixed-based cold cuts or red meat or poultry imitations. However, only the protein content of the sausages imitations differed. Specifically, wheat-based sausage imitations contained more protein than the soy-based and mixed versions. In contrast, numerous distinctions were detected between groups of plant-based dairy substitutes based on their matrix. Energy, protein, total fat, saturated fatty acids, carbs, sugars, and fiber varied among plant-based milk imitations [44].

Comparing milk imitators by their ingredient bases revealed (Table 15 & Figures 18-22) significant differences between milk imitations. Energy and salt content were the only nutrients that did not differ.

Specifically depending on the ingredient, coconut milk presented the lowest content in energy, while pulse-based milk imitations were the highest in protein (3,3g/100g) compared to nut-(0,8g/100g), coconut- (0,2g/100g), grain-(0,7g/100g) and mixed-based (0,5g/100g). Fat content among categories were very close, while pulse-based imitations having the highest content (2,25g/100g). Coconut-based milk imitations were those with the highest saturated fat content (1,4g/100g). Carbohydrates and sugar content was significant higher on grain milk imitations (9,6g/100g and 5,55g/100g, respectively), especially when compared to nut-based (3,1g/100g and 2,4g/100g) and other/mixed ones.

Differences in-between the plant-based yogurt imitations' (Figure 26) category found at protein content, SFA and salt. In particular, protein content was the highest at yogurt imitations made from pulses (3,8g/100g) , especially when compared with grain-based (0,85g/100g). Total fat content was in coconut-based (5g/100g), when compared to grain-based (1,2g/100g), whereas coconut-based yogurt imitations presented the highest levels of SFA and salt.

In-between plant-based cheese imitation (Figure 25), energy, protein, total fat, SFA, carbs, sugars, and salt levels were different. Vegetable oil-based cheese imitations seemed the poorest protein but the richest in saturated fatty acids and salt. When comparing cheese imitations among different based ingredients pulse-base had the highest protein level (15,5g/100g), whereas, vegetable oil-based cheeses had the highest saturated fat content (21g/100g) and nut-based (cashew) cheeses had the highest total fat and carbohydrate content.

Table 14 Nutritional composition of meat products according to the main ingredient used as an alternative source of protein.

Nutrients	**Cold Cuts Imitations (*n* = 18)**				**Sausage Imitations (*n* = 19)**				**Red Meat Imitations (*n* = 43)**				**Poultry Meat Imitations (*n* = 16)**			
	Soy-Based (*n* = 1)	**Wheat-Based (*n* = 9)**	**Other (*n* = 8)**	***p*-Value**	**Soy-Based (*n* = 3)**	**Wheat-Based (*n* = 12)**	**Other (*n* = 4)**	***p*-Value**	**Soy-Based (*n* = 9)**	**Wheat-Based (*n* = 12)**	**Other (*n* = 22)**	***p*-Value**	**Soy-Based (*n* = 8)**	**Wheat-Based (*n* = 3)**	**Other (*n* = 5)**	***p*-Value**
Energy (kcal)	166.0 (166.0, 166.0)	244.0 226.5, 269.5)	197.5 (172.5, 221.8)	0.017	69.0 (237.0, -)	51.5 213.8, 269.0)	162.5 (54.5, 223.3)	0.034	221.0 (135.0, 278.0)	222.0 (165.8, 242.2)	236.5 (202.0, 250.8)	0.820	195.5 (186.5, 221.8)	229 (212, -)	249.0 (215.5, 258.5)	0.142
Protein (g)	15.5 (15.5, 15.5)	29.3 (27.3, 33.5)	5.1 (3.5, 31.0)	0.044	4.4 14.0, -)	9.2 24.7, 31.1)	17.0 (7.0, -)	**0.005**	14.9 14.5, 24.0)	25.5 (19.7, 27.6)	16.0 (14.5, 19.3)	0.02	11.4 (9.5, 13.8)	13.7 (10.5, -)	13.0 (6.5, 17.0)	0.832
Fat (g)	10.0 (10.0, 10.0)	12.2 (8.4, 13.5)	16.0 (6.8, 18.0)	0.192	8.0 17.7, -)	1.8 10.4, 13.3)	9.0 (6.8, -)	0.024	10.7 (2.8, 18.2)	9.9 (3.2, 12.4)	14.3 (11.5, 16.6)	0.020	7.9 (6.5, 10.8)	7.8 (7.6, -)	15.3 (4.2, 17.5)	0.689
SFA (g)	2.6 (2.6, 2.6)	2.6 (1.1, 5.9)	1.5 (1.3, 2.1)	0.599	.5 (2.2, -)	.2 0.9, 1.3)	7.0 (0.9, -)	0.186	4.0 (0.4, 9.3)	1.2 (0.8, 1.8)	5.3 (1.1, 9.5)	0.090	1.2 (0.7, 3.1)	0.8 (0.8, -)	1.1 (0.6, 12.6)	0.812
Carbohydrates (g)	3.0 (3.0, 3.0)	5.4 (3.0, 6.5)	5.9 (2.0, 7.0)	0.737	.0 3.0, -)	.5 3.6, 5.8)	4.3 (3.0, -)	0.749	5.0 (2.9, 14.8)	6.6 (2.8, 12.0)	7.7 (4.7, 10.4)	0.785	16.6 (12.8, 20.0)	20.8 (15.7, -)	14 (11.6, 15.3)	0.091
Sugars (g)	2.0 (2.0, 2.0)	1.5 (0.4, 2.4)	1.9 (0.9, 2.8)	0.763	.1 0.7, -)	.6 0.4 , 2.0)	0.5 (0.0, -)	0.097	0.9 (0.5, 1.1)	1.5 (1.1, 2.7)	0.8 (0.6, 2.5)	0.293	0.9 (0.5, 4.6)	2.7 (0.5, -)	1.6 (1.4, 2.1)	0.450
Fiber (g)	-	-	4.4 (4.1, 5.0)		.9 0.0, -)	2.4, -)	3.2 (3.2, 3.2)	**0.000**	5.7 (2.6, 12.5)	4 (1.5, -)	4.1 (2.0, 5.3)	0.649	2.8 (1.6, 6.5)	5.0 (5.0, 5.0)	4.7 (3.2, -)	0.759
Salt (g)	1.9 (1.9, 1.9)	1.9 (1.4, 2.5)	2.4 (2.1, 2.8)	0.334	.9 1.4, -)	.6 1.4, 1.8)	1.3 (1.2, -)	0.054	1.3 (0.9, 1.4)	1.7 (1.3, 1.9)	1.3 (1.0, 1.7)	0.096	1.3 (1.1, 1.5)	0.9 (0.9, -)	1.4 (1.1, 1.9)	0.638

Table 15 Nutritional composition of dairy products according to the main ingredient used as an alternative source of protein or fat.

Nutrients	**Milk Imitations (*n* = 221)**						**Yogurt Imitations (*n* = 40)**					**Cheese Imitations (*n* = 80)**				
	Nut-Based (*n* = 64)	**Coconut-Based (*n* = 18)**	**Grain-Based (*n* = 62)**	**Pulse-Based (*n* = 20)**	**Mixed (*n* = 16)**	***p*-Value**	**Nut-Based (*n* = 14)**	**Coconut-Based (*n* = 8)**	**Grain-Based (*n* = 6)**	**Pulse-Based (*n* = 12)**	***p*-Value**	**Nut-Based (*n* = 2)**	**Pulse-Based (*n* = 9)**	**Mixed (*n* = 3)**	**Vegetable oil Based (*n* = 66)**	***p*-Value**
Energy (kcal)	37.0 (27.0, 51.0)	30.5 (20.0, 40.3)	55.0 (47.8, 61.0)	50.0 (41.0, 61.0)	2.0 28.8, 56.8)	0.001	9.5 57.8, 110.0)	1.0 76.8, 111.3)	4.0 84.8, 96.5)	5.0 59.8, 80.8)	0.154	38.0 429.1, -)	65.0 120.0, 200.5)	81.0 166.0, -)	85.0 277.0, 305.0)	0.001
Protein (g)	0.8 (0.6, 1.0)	0.2 (0.1, 0.4)	0.7 (0.5, 1.0)	3.3 (3.0, 3.7)	.5 0.4, 1.0)	0.001	.9 0.8, 2.3)	.6 0.6, 2.1)	.7 1.2, 2.1)	.8 3.6, 3.9)	0.001	.9 7.1, -)	6.0 13.0, 18.5)	.7 2.5, -)	.0 0.0, 0.5)	0.001
Fat (g)	1.9 (1.4, 2.5)	1.7 (1.2, 2.7)	1.3 (1.0, 1.5)	2.2 (1.8, 2.5)	1.6 (0.9, 2.3)	0.001	.4 1.7, 5.2)	.4 3.0, 5.3)	.1 0.9, 3.2)	.2 2.1, 2.3)	0.032	0.2 39.4, -)	.0 7.0, 13.0)	6.3 15.3, -)	3.0 21.0, 24.0)	0.001
SFA (g)	0.2 (0.1, 0.3)	1.4 (1.0, 2.5)	0.2 (0.2, 0.3)	0.4 (0.3, 0.5	0.2 (0.1, 0.9)	0.001	0.4 (0.1, 0.5)	3.8 (1.7, 4.5)	0.3 (0.1, 0.4)	0.3 (0.3, 0.4)	0.001	16.0 (10.1, -)	1.6 (1.2, 2.2)	1.4 (1.2, -)	21.0 (18.4, 21.0)	0.001
Carbo-hydrates (g)	3.1 (1.5, 6.9)	2.0 (1.6, 3.6)	9.6 (7.7, 11.0)	3.2 (1.0, 6.4)	4.0 (1.5, 9.5)	0.001	11.2 (4.7, 15.9)	10.1 (6.1, 15.4)	15.0 (13.4, 20.0)	9.9 (2.9, 12.0)	0.049	40.9 (4.9, -)	1.1 (0.8, 2.0)	9.7 (0.3, -)	21.9 (15.7, 23.0)	0.001
Sugars (g)	2.4 (0.3, 4.1)	1.5 (0.5, 2.6)	5.6 (4.4, 7.5)	3.3 (1.6, 6.3)	1.4 (0.2, 4.6)	**0.001**	1.9 (0.6, 11.0)	8.1 (1.5, 12.1)	8.5 (4.4, 11.7)	9.2 (1.4, 11.0)	0.825	1.6 (0.1,	0.5 (0.5, 0.6)	0.3 (0.3, -)	0.0 (0.0, 0.1)	**0.001**
Fiber (g)	0.8 (0.4, 1.6)	0.2 (0.1, 0.6)	0.8 (0.5, 1.2)	0.6 (0.5, 0.9)	0.2 (0.1, 0.5)	**0.001**	1.1 (0.8, 1.6)	0.8 (0.3, -)	1.0 (0.5, 1.1)	0.5 (0.5, 0.5)	0.421	-	2.0 (2.0, 2.0)	2.1 (0.4, -)	1.7 (0.5, -)	0,953
Salt (g)	0.1 (0.1, 0.1)	0.1 (0.1, 0.1)	0.1 (0.1, 0.1)	0.1 (0.1, 0.2)	0.1 (0.1, 0.1)	0.053	0.1 (0.0, 0.1)	0.2 (0.2, 0.4)	0.1 (0.1, 0.1)	0.1 (0.1, 0.1)	**0.010**	1.1 (1.0, -)	1.4 (0.1, 1.8)	1.0 (0.8, -)	2.0 (1.8, 2.2)	**0.001**

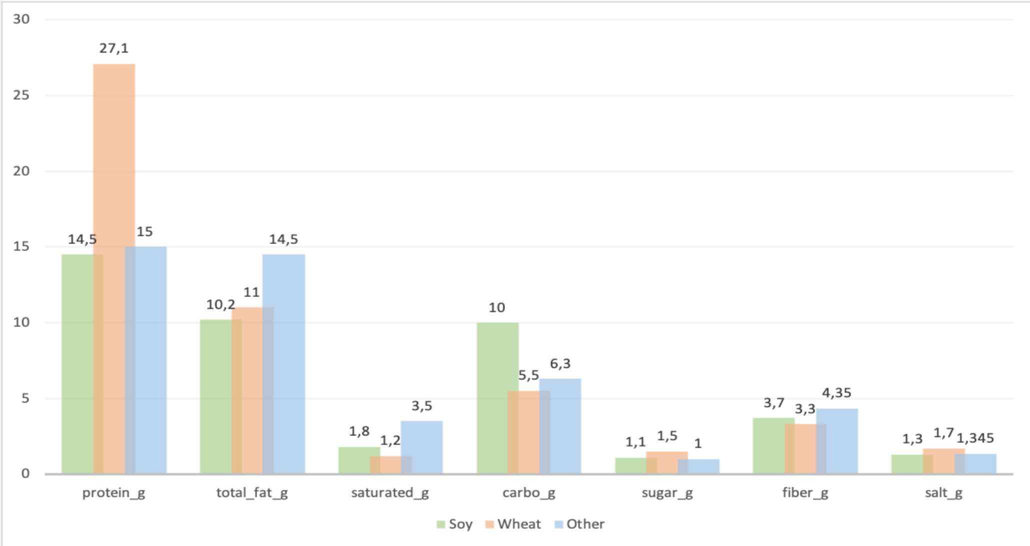

*Figure 15 Nutritional composition of **meat** imitations among different categories (soy-, wheat- and other-based) on main ingredient. Values indicate medians of each nutrient protein, total fat, saturated fat, carbohydrates, sugar, fiber and salt expressed in grams.*

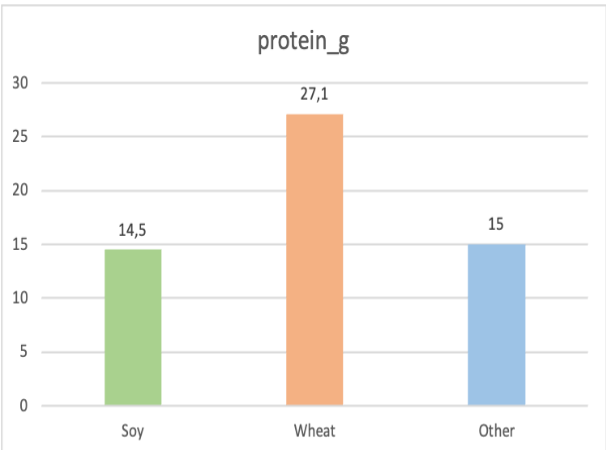

*Figure 16 Protein content of **meat** imitations among different categories (soy-, wheat- and other-based) on main ingredient. Values indicate medians (g/100g).*

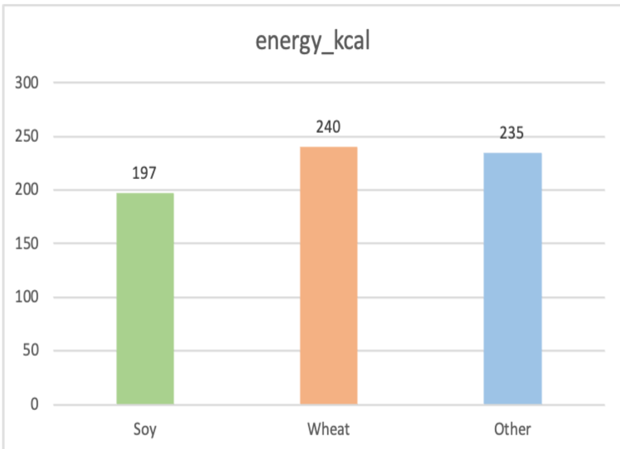

*Figure 17 Energy content of **meat** imitations among different categories (soy-, wheat- and other-based) on main ingredient. Values indicate medians (kcal/100g).*

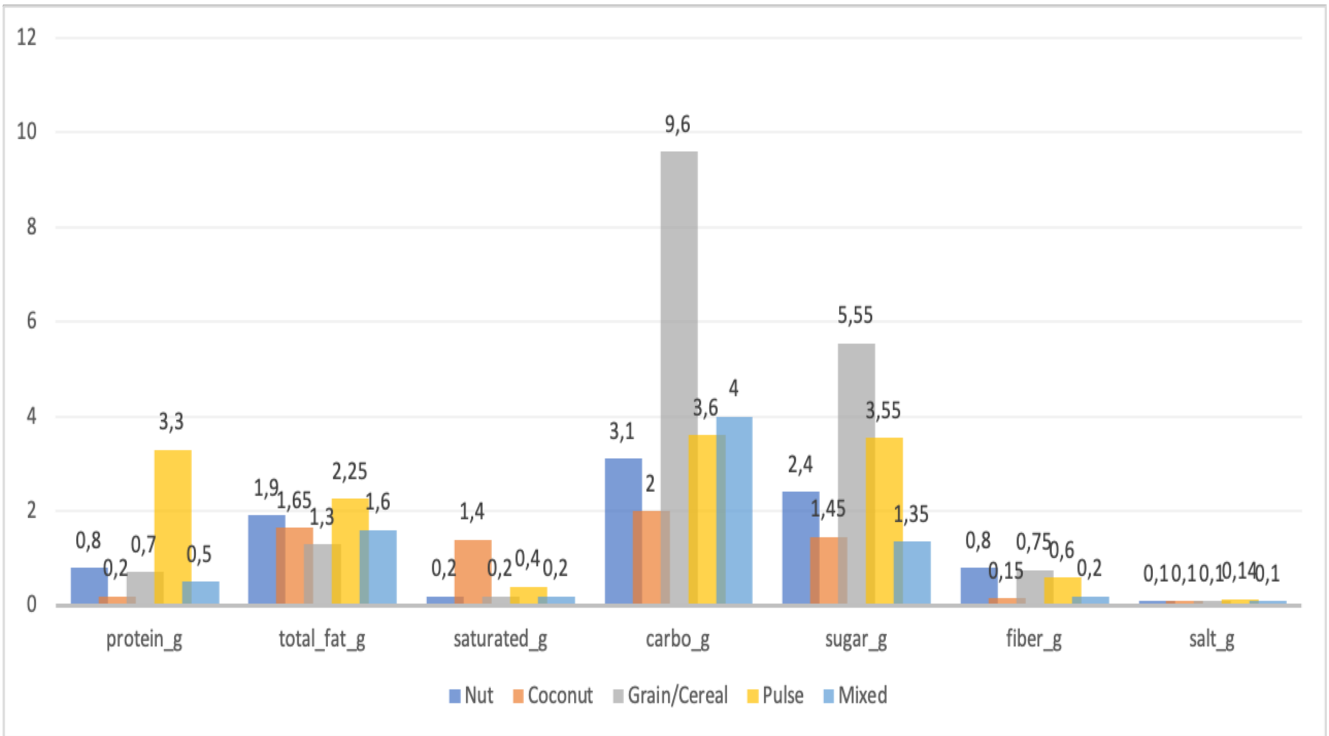

*Figure 18 Nutritional composition of **milk** imitations among different categories (nut-, coconut-, grain/cereal-, pulse-, mixed-based) on main ingredient. Values indicate medians of each nutrient protein, total fat, saturated fat, carbohydrates, sugar, fiber and salt expressed in grams.*

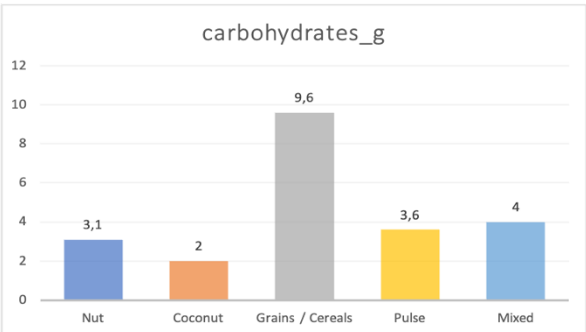

*Figure 19 Carbohydrates content of **milk** imitations among different categories (nut-, coconut-, grain/cereal-, pulse-, mixed-based) on main ingredient. Values indicate medians (g/100g).*

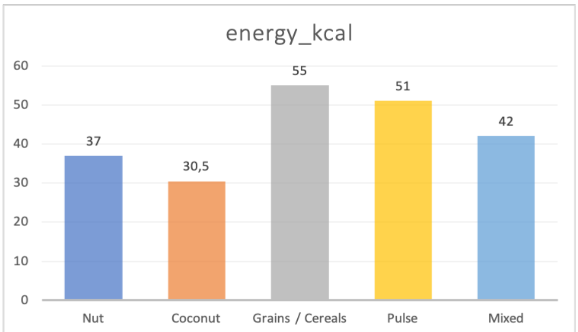

*Figure 20 Energy content of **milk** imitations among different categories (nut-, coconut-, grain/cereal-, pulse-, mixed-based) on main ingredient. Values indicate medians (kcal/100g).*

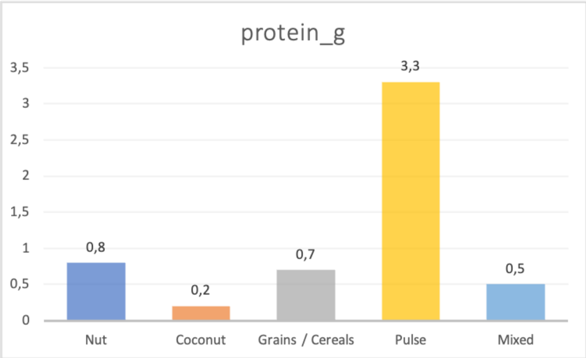

Figure 21 Protein content of ***milk*** *imitations among different categories (nut-, coconut-, grain/cereal-, pulse-, mixed-based) on main ingredient. Values indicate medians (g/100g).*

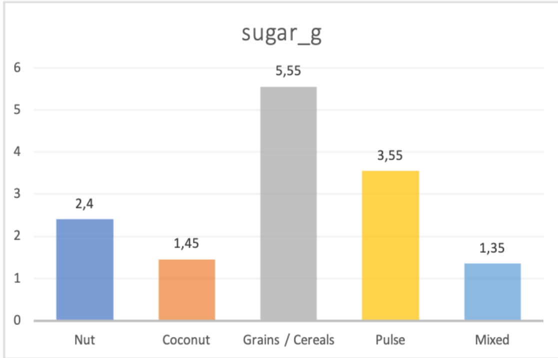

Figure 22 Sugar content of ***milk*** *imitations among different categories (nut-, coconut-, grain/cereal-, pulse-, mixed-based) on main ingredient. Values indicate medians (g/100g).*

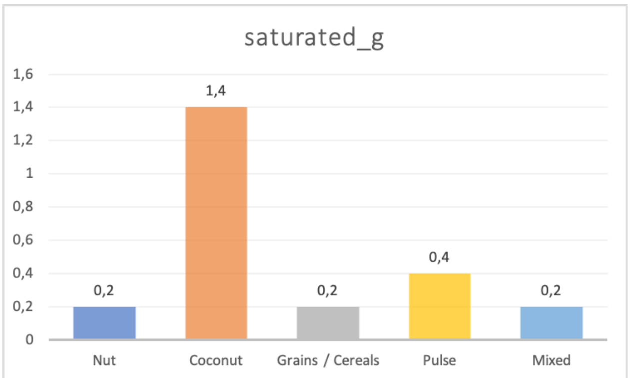

Figure 23 Saturated fat content of ***milk*** *imitations among different categories (nut-, coconut-, grain/cereal-, pulse-, mixed-based) on main ingredient. Values indicate medians (g/100g).*

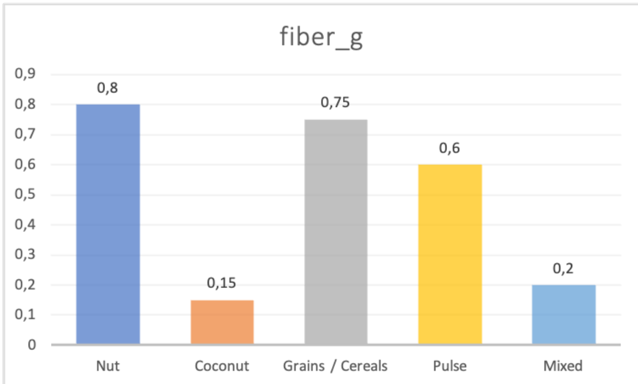

Figure 24 Fiber content of ***milk*** *imitations among different categories (nut-, coconut-, grain/cereal-, pulse-, mixed-based) on main ingredient. Values indicate medians (g/100g).*

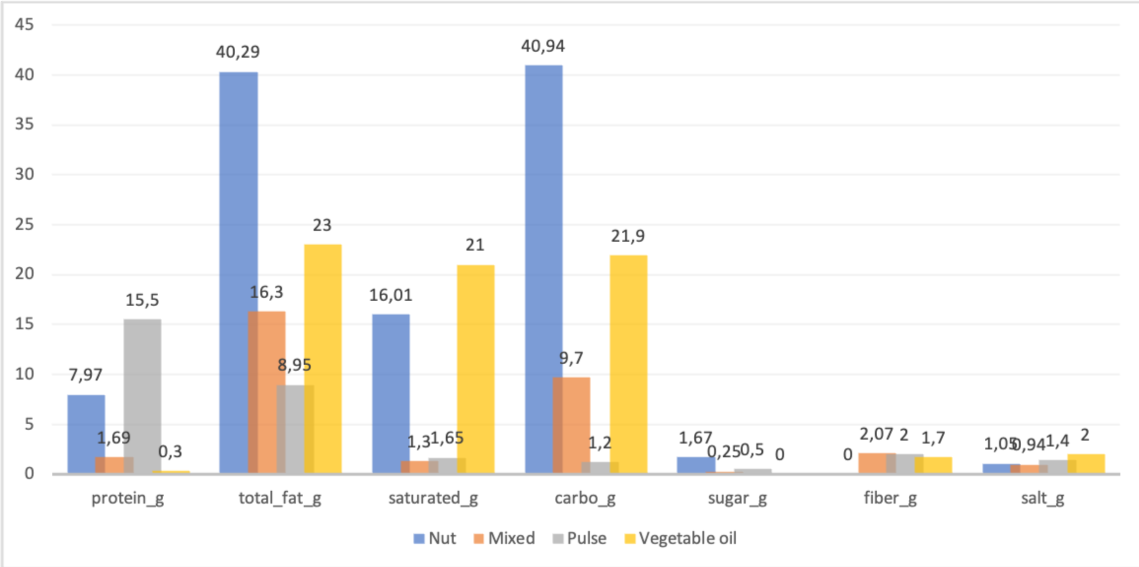

*Figure 25 Nutritional composition of **cheese** imitations among different categories (nut-, mixed-, pulse-, vegetable oil-based) on main ingredient. Values indicate medians of each nutrient protein, total fat, saturated fat, carbohydrates, sugar, fiber and salt expressed in grams.*

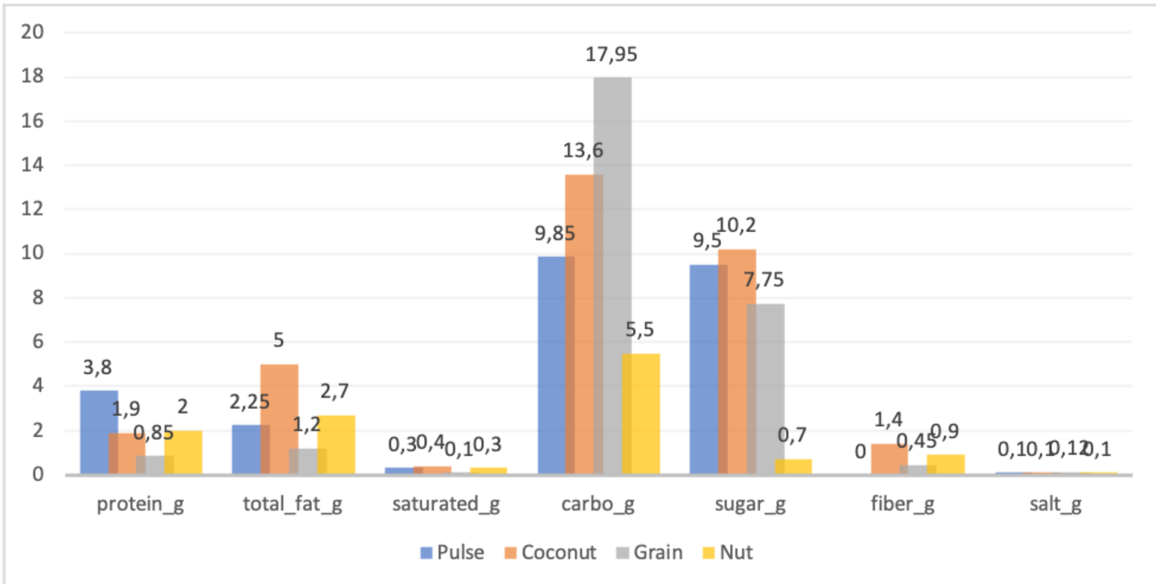

*Figure 26 Nutritional composition of **yogurt** imitations among different categories (pulse-, coconut-, grain-, nut-based) on main ingredient. Values indicate medians of each nutrient protein, total fat, saturated fat, carbohydrates, sugar, fiber and salt expressed in grams.*

3.6 NutriScore profiling

The Nutri-Score system was used to evaluate the nutrient profile of the meat and dairy, imitations and to compare with their animal-based counterparts (Figure 27 and 28). FSAm-NPS Score and therefore Nutri-Score categories A-E were estimated. Nevertheless, no one of the products studied gained positive points for FV%. Following the guidance on quantifying the fruit, vegetable, pulse, nut and rapeseed oil, walnut and olive oils content of processed product, after defining which exact ingredients of the specific products in our study, soya beans, pulses, coconut, nuts (almond, walnut, cashew, walnut, olive and rapeseed oil belonged to the groups that are capable to gain extra points and furthermore could be defined as FVPNOs (according to Eurocode 2). For their inclusion in the calculation, the form in which each of the above exists in the product imposes numerous restrictions.

The acceptable levels of processing for inclusion in the calculation depend on the health benefits associated with fruits and vegetables. Processing can result in the loss of fiber and micronutrients such as vitamins. The permissible processing levels for inclusion in the calculation depend on the health benefits of fruits and vegetables. Fiber and micronutrients may be also lost during the food's processing. Therefore, it would not be valid to count ingredients such as concentrated fruit juice sugars, which are added to products to enhance their sweetness, in the same manner as entire fruits and vegetables. For the purpose of calculating a score, entire fruits and vegetables (including those that are cooked and dried) and minimally processed fruits, vegetables, and pulses (peeled, sliced, canned, frozen, purees, pulp, grilled, roasted, or marinated) only count. However, fruits, vegetables, legumes, and nuts are only considered in the calculation when their content exceeds 40 percent. Fruits, vegetables, and pulses that undergo additional processing (such as concentrated fruit juice sugars, powders, freeze-drying, candied fruits, fruits in stick form, and flours that result in water loss) are typically excluded. For instance, soy proteins cannot be considered as vegetables. Fried vegetables that are thick and only partially dehydrated by the process can be taken into account, whereas crisps which are thin and completely dehydrated are excluded. Coconut on the other hand, presents particular issues because it is consumed differently than other nuts. The fresh coconut flesh should be scored as fruit, the water of the coconut (also known as "coconut water") should be scored as fruit juice (coconut water is the liquid that is extracted from the center of an unripe green coconut without extracting or pressing the coconut flesh), and the coconut milk that is obtained by extracting or pressing the coconut flesh of a ripe coconut should be scored as fruit. However, in order to factor coconut milk into the calculation, it needs to be regarded as food. Coconut cream should be counted as additional fat rather than fruit because it does not contain any fruit. Desiccated coconut and dried coconut are essentially the same product, and neither should be included in the calculation. Any other coconut form that has been processed further than the original product should not be used.

Specifically, for meat imitations in our study, because the form of soy used form them when referred to soy-based, soy was concentrated soy protein that indicates further processes which may cause a loss in fiber and vitamins. Therefore it cannot be included in the calculation of Nutri-Score. On wheat-based meat imitations, the most prominent form of wheat was seitan, which consisted of a combination of water, wheat protein, and textured protein as its primary ingredients. Even if some products did not contain concentrated or textured protein, their percentage was not capable to reach 40% to be included in the calculation. FV% only counts when their content exceeds 40 %, as previously stated. For other/mixed- based ones, flours/powders of vegetable proteins were used, and also were excluded from the calculation.

For dairy imitations, specifically in milk, the fruit (coconut) ingredient was either as concentrated fruit, either from puree or coconut water. The only form of the above could have been counted is coconut water but, neither this neither none of the other forms exceeded 40%. Rapeseed oil was also in low percentage on milk imitations. For yogurts, soya juice appeared as the main component in many of them but, its composition was almost 90% water and up to 10% of soybeans. This means that the percentage is very low to be counted. Fruit formulas had the same problem. Either coconut milk was not enough to be counted or more complicated fruit products including water, thickening agents had concentrated fruit juices in low percentages. Nuts either on milk or yogurt imitations did not exceed the 4% per 100g or the product. Consumers are encouraged to take note of the quantity of fat (which they should avoid) and calcium contained in cheese by the guidelines for cheese calculation (encourage). Furthermore, there is a strong linkage between the amount of protein and calcium in dairy products, yet calcium is not to mandatory declaration. This leads to a modification of cheese calculation in order ensure that protein content is always counted (which would otherwise be precluded by their salt, calorie and saturated fatty acid content, as these result in a total N value exceeds 11). This guarantees that their calcium levels are taken into account. Thus, protein content was always taken into account, no matter if N points were less than 11 or more. The thresholds for the other food categories remain the same [cheese nutritional score=Total N points-Total P points]. Cheese imitations in our study could have gain extra points from rapeseed and walnut oil, since they are mostly vegetable oil-based, but this kind of oils were complementary to coconut oil which was the most common used by manufacturers. The percentage of rapeseed was either too low or not mentioned (which may indicates of an underestimation of Nutri-Score).

In plant-based meat imitation products, 12% was graded as A, 16.8% as B, 30.5% as C, 35.8% as D, and 5.3% as E (Table 16). The majority of plant-based meat products and animal-based meat products were given grades of D, with the exception of plant-based poultry imitations, which were most frequently given grades of C (Figure 19). The FSAm-NPS Score for animal-based sausages was found to be the greatest (FSAm-NPS Score = +23), followed by the score for red meat imitations (FSAm-NPS Score = +22), while the score for poultry and red meat imitations was found to be the lowest (FSAm-NPS Score = -7 for both cases).

Concerning the interquartile range of each imitation category, sausage imitations (light blue) had the biggest range of FSAm-NPS scores while poultry imitations (light yellow) had the smaller distribution. Cold cut imitations most frequent scores were D and C in 38,9%. B was the second often score, followed by A and E 5.6% in both case respectively. Sausage imitations (appeared with a score D the most, followed by C(31,6%), B (15.8), E (5,3%). Red meat imitations were also detected with D (35,7%), C (26,2%), B and A (16,7%), and E (4,8%). Poultry imitations appeared with C score (31.3%), B score (25,5%), A and D score (18,8% respectively) and E (6,3%).

There was no significant different found in any of the meat categories between the means of the FSAm-NPS Scores of meat products originated from plants and those originated from animals. The percentage of plant-based meat imitations that met the criteria for an A grade was lower than 20%. To be more specific, the predominance of Nutri-Score Category A was 18.8% for chicken imitations, followed by plant-based red meat imitations (16.7%), cold cut imitations, and then poultry imitations again. Sausage imitations had no score category A. Score B and D was detected in all meat and meat imitation categories. For score B red meat imitations had the highest frequency (44,4%) followed by poultry and sausages, both animal based. In general score B in imitations was not detected that often as in animal-based counterparts. Plant-based sausage imitations and animal-based red meat did not include products classified in the Nutri-Score Category A in their interquartile range. (Outliers did not considered in the results).

Both plant-based and animal-based milk products were graded B most frequently (Fig 28). The proportion of animal-based products classified as Nutri-Score Category A was greater (35.8%) than that of plant-based milk imitations (21.3%).

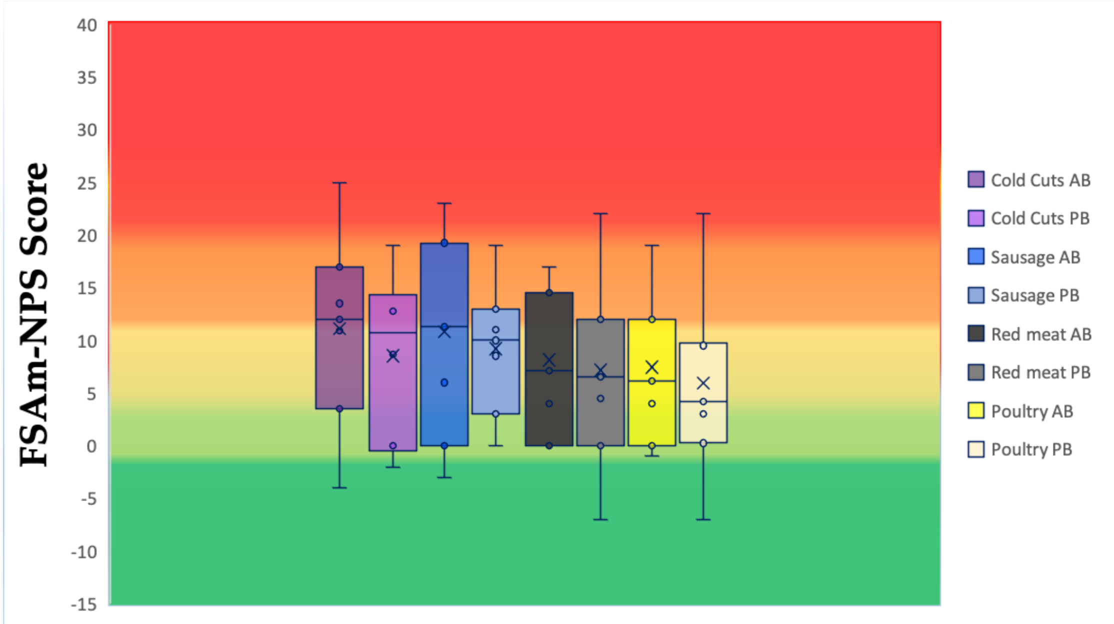

Figure 27 Distribution of plant-based meat imitations and their animal-based equivalents within the Nutri-Score categories. (Overall Boxplots of animal-based (AB) and plant-based (PB) products within the food categories analyzed. Dark green: Nutri-Score

Plant based milk imitations' distributions was smaller than their counterparts, while the first has its 76,3% of the products scored with B (Table 17). Milk imitations had no E and just one product with a D Nutri-Score. On the same pattern, the majority of animal-based milk received a B score (62.5%), followed by an A (35,8%). On the same pattern the majority of animal based milk has attributed a B score (62,5%) and A score followed with 35,8%. In animal-based milk neither D or E score is detected. Most plant-based yogurt imitations were rated as Nutri-Score Category B, whereas animal-based yogurt were classified as Nutri-Score Category C. No yogurt, whether plant-based nor animal-based, had a D or E Nutri-Score categories. Plant-based yogurt imitations presented a statistically significant higher mean of FSAm-NPS Score compared to their animal-based equivalents. Yogurt imitations were detected with B score the most (48,9%). Score A (27,7%) and C (23,4%) followed, without any D or E. The percentage of animal-based yogurt with an A score is the highest of any dairy product, whether plant- or animal-based (52.7%). Most plant-based cheese imitations were classified as Nutri-Score Category E, whereas animal-based were classified as Nutri-Score Category D. Seventy-one percent of plant-based cheese imitations were classified as Nutri-Score Category E, followed by C (9.6%), D and A (7.2% each), and B (4.4%). The mean FSAm-NPS score of plant-based cheese imitations was significantly higher than that of their animal-based counterparts. Cheese imitations was the only category whose E score exceeded 50 % of the total scores on products. The distributions of plant- and animal-based cheeses are quite similar but Nutri-

Score of the latter are in general lower. Lastly, In imitation cheeses, the majority of products were found to have the highest E-score % compared to any other plant-based, meat, or dairy imitation.

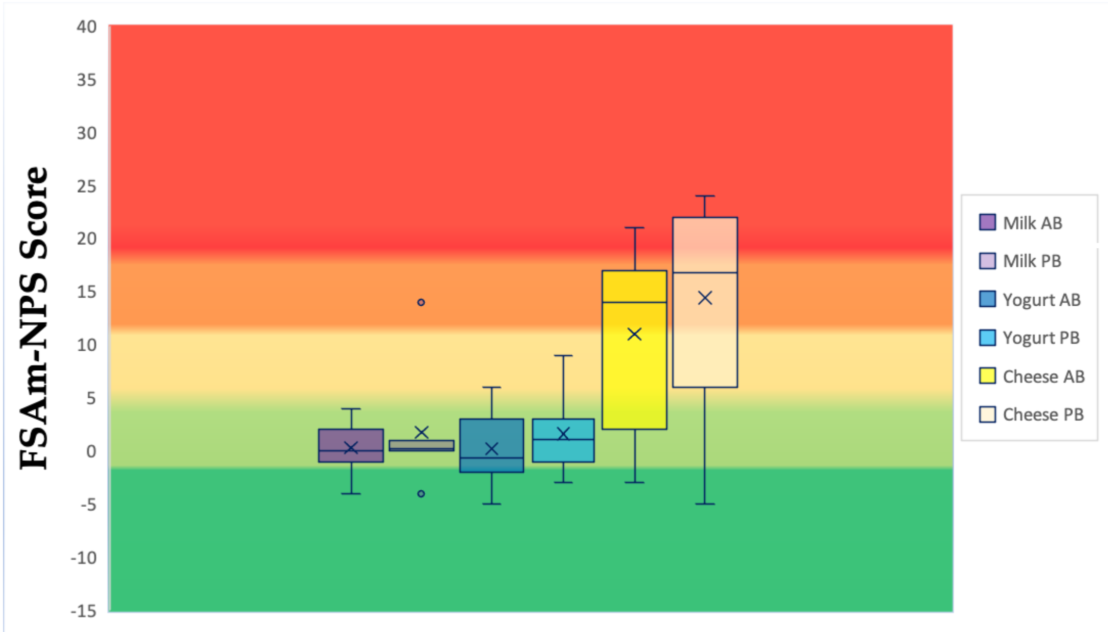

Figure 28 Distribution of plant-based dairy imitations and their animal-based equivalents within the Nutri-Score categories. (Overall Boxplots of animal-based (AB) and plant-based (PB) products within the food categories analyzed. Dark green: Nutri-Score Category "A", light green: Nutri-Score Category "B, yellow: Nutri-Score Category "C", light-orange: Nutri-Score Category "D", and dark orange: Nutri-Score Category "E".

Table 16 Performance of the Nutri-Score nutrient profiling system at meat and meat imitations food groups

Food Group	Mode (Range)	A [n(%)]	B [n(%)]	C [n(%)]	D [n(%)]	E [n(%)]
Cold Cuts	D (A-E)	4 (5.2)	13 (16.9)	9 (11.7)	36 (46.8)	15 (19.5)
Cold Cuts Imitations	D (A-E)*	1 (5.6)	2 (11.1)	7 (38.9)	7 (38.9)	1 (5.6)
Sausage	D (A-E)	3 (7.9)	11 (28.9)	-	13 (34.2)	11 (28.9)
Sausage Imitations	D (B-E)	-	3 (15.8)	6 (31.6)	9 (47.4)	1 (5.3)
Red meat	D (B-D)	-	4 (44.4)	1 (11.1)	4 (44.4)	-
Red meat imitation	D (A-E)	7 (16.7)	7 (16.7)	11 (26.2)	15 (35.7)	2 (4.8)
Poultry	D (A-E)	2 (10.5)	7 (36.8)	1 (5.3)	8 (42.1)	1 (5.3)
Poultry imitation	C (A-E)	3 (18.8)	4 (25.0)	5 (31.3)	3 (18.8)	1 (6.3)

- *C and D percentages are equal.*

Table 17 Performance of the Nutri-Score nutrient profiling system at dairy and dairy imitations food groups

Food Group	Mode (Range)	A [n(%)]	B [n(%)]	C [n(%)]	D [n(%)]	E [n(%)]
Milk	B (A-C)	43 (35.8)	75 (62.5)	2 (1.7)	-	-
Milk Imitations	B (A-D)	51 (21.3)	183 (76.3)	5 (2.1)	1 (0.4)	-
Yogurt	A (A-C)	79 (52.7)	56 (37.3)	15 (10)	-	-
Plant-based yogurt	B (A-C)	13 (27.7)	23 (48.9)	11 (23.4)	-	-
Cheese	D (A-E)	9 (4.20	45 (21.2)	17 (8.0)	127 (59.9)	14 (6.6)
Plant-based Cheese	E (A-E)	6 (7.2)	4 (4.7)	8 (9.6)	6 (7.2)	59 (71.1)

4.DISCUSSION

HelTH update was the main focus of this study. The presence of imitation products necessitated a thorough examination of food information and an appreciation of the limitations of the dataset. Any innovation that arises will be supported by new adaptations in the methodology and these new adaptations that have taken place will serve as a foundation for making modifications and developing new rules in the future. In terms of the new trend in the food market that is centered on processed food, the addition of new aspects concerning processing methods will most definitely be a modification that can be added in a possible update of HelTH.

The Greek market is becoming increasingly popular with vegan alternatives to meat and dairy products [41,45]. According to our knowledge, this is the first investigation to assess the nutritional value of plant-based meat and dairy alternatives sold in Greece. These innovative products found are in line with global trends for vegan products. More specifically, it was always at least one non-animal product available for purchase in the supermarket's conventional category of meat and dairy products. However, the primary component that was used varied depending on the category and the subcategory of which exact product do they mimic.

In the majority of meat and dairy substitutes, water was listed as the first component in the ingredient list, and the source of the specific protein was not included until the second row. For imitations of cold cuts and sausage, wheat was the predominant ingredient, while soy was the predominant ingredient for imitations of poultry, and for imitations of red meat, soy, wheat, and pulses were equally prevalent. Cheese was the most intriguing subcategory of dairy substitutes, as it was the only subcategory in which vegetable oils were the primary ingredient for 80.9% of all products. For milk imitations, the most common ingredients were nuts and grains, while for yogurt imitations, it was nuts and soy.

An important finding was the nutritional composition of meat and dairy imitations, particularly in comparison with animal-based counterparts. The energy content of meat imitations was similar to that of their animal-based counterparts. Sausage substitutes contained less saturated fatty acids and salt than their animal-based counterparts, but their salt content is still considered high. In addition, sausage imitations contained more protein than their animal-based counterparts. In comparison to their animal-based counterparts, poultry and cold cuts imitations had more sugars and carbohydrates respectively, than their corresponding equivalents. It is essential to note that starch sources are utilized in meat imitations due to their properties relating to texture improvement, shelf life extension, cohesiveness, and elasticity. These characteristics are mostly connected with starches' capacity to gelatinize into stable gels [50]. This is in line with research who indicates soy as the preferred component-due to its high moisture- of poultry imitates and wheat as red meat/ original preserved imitate due to the difference in their final look and texture [10,25,27,51,52].

In dairy alternatives, only milk imitations showed a lower energy content than animal milk among all dairy imitations. Yogurt and cheese imitations contained higher carbohydrates and fiber, but yogurt alternatives included more sugars. In contrast, milk imitations had less [30] sugar than their animal-based counterparts. Changes in carbohydrate content could be connected with the natural carbohydrate-rich composition of plant-based foods [53–55], as such the usage of plant-based matrix is also linked to higher fiber content [50]. All categories of plant-based dairy imitations contained less protein than their animal-based counterparts. The findings of the present study are consistent with those of studies conducted in other countries on the nutritional composition of plant-based products. For example, the Italian non-dairy milk FLIP study [56] found that plant-based beverages had a lower total amount of energy and sugar when compared to their counterparts that were derived from animals. Our findings were in agreement with those of other researchers who found that milk imitations made from plants include a significantly lower concentration of protein when compared to animal-based milk products [57]. Our observations, along with those of others, indicated that cheese imitators have a high level of SFA [58].

Regarding plant-based diets, protein intake but also protein quality are extremely important factors. Protein bioavailability and digestibility is linked to the product's amino acid profile. Out of the full range of twenty amino acids, the nine essential amino acids are these that needed to be consumed, but essential amino acids cannot be synthesized by any endogenous human metabolic pathway. Plant-based protein sources, usually do not contain a satisfactory amount of amino acids compared to animal meat or dairy. Furthermore, they contain phytate and dietary fibers that inhibit protein digestion and bioavailability [59]. For this reason one or more sources have to be combined. Food such as nut, seed, legumes, grains and vegetables are considered incomplete proteins because they are missing one or more amino acids. Cereals are low in lysine but high in methionine, while pulses are the opposite-they are a source of lysine and has no methionine. Rice, on the other hand is low in lysin, but a great source of methionine. As the other/mixed meat imitation category of our study indicated, pulses usually are combined with rice in order to be complementary and reach the adequate intake [59]. Regarding micronutrients declared on-pack, plant-based dairy, especially beverages, were mostly fortified with Calcium, Potassium, Vitamins of B complex (B2, B12), and/or D, while meat imitations were enriched with B12 and Iron (Fe). The amount of fortification was almost the same in all fortification categories per product, reaching the adequate intake. Other studies have shown that iron, among other micronutrients, is primarily affected by the processing method, and even though some products are fortified, their estimated bioavailability is low. In addition plant-based proteins productions undergo harsh conditions. Thermal treatment and shear stress alter intramolecular and intermolecular bonds and result in protein denaturation. As a result, the protein structure denatures and the product's bioavailability and digestibility change. Overall, the selection of a suitable protein source and processing method can be used to improve the digestibility and bioavailability of plant-based proteins, thereby enhancing the nutritional profile of plant-based imitations [30,59].

The variety of ingredients had an effect on the amount of protein that was contained in the products. Only in soy-based sausages was there a significant difference in protein content, and it was in favor of wheat-based formulations. This was not the case when comparing other meat imitations, where no significant differences were found. In contrast, formulations based on pulses had the highest protein level among dairy substitutes. In particular, vegetable oil-based cheeses lacked protein, as opposed to fat. It is important to note that in our analysis, particularly for meat imitations, the nutritional makeup was similar across brands from the same manufacturer. This may imply that the manufacturer uses a same recipe to create various products. This suggests that there is a lack of diversity in products offered when it comes to imitations of meat products, as they are all made from almost the same recipe. Additionally, the substitute protein and fat ingredients used in the imitation meat and dairy products sold in Greece were almost always the same as those discovered in other studies.

An excessive use of ultra-processed foods has developed into a public health concern The consumption of energy from UPFs has been associated with increased risks of obesity, type 2 diabetes, metabolic syndrome, hypertension, cardiovascular disease, depressive symptoms, cancer and overall mortality. According to the NOVA food classification system, foods are placed into one of four categories: unprocessed, processed, ultra-processed, and culinary ingredients. These categories are ostensibly determined by the degree of industrial processing as well as the reason for processing in the first place. Salt, sugar, and fat are common ingredients in UPFs, and they are frequently present in higher concentrations in processed foods. The most typically from manufacturers ingredients use, such as plant protein isolates, modified starches and oils and additives, including colorants, flavors and/or flavor enhancers, emulsifiers, and non-sugar sweeteners (xanthan gum, locust bean gum, methylcellulose, ascorbic acid, citric acid, ascorbic acid, methylcellulose, carrageenan gum, citric acid, ascorbic acid, xanthan gum, locust bean gum, b-carotene, and so many other ingredients), which are in the formulations of most plant-based meat and dairy alternatives, classify them into the UPFs NOVA category. This is because they were created from food components and contained multiple ingredients that were highly processed in an industrial process, usually involving mixing and forming into the desired product shape. Plant-based diets contrastingly, such as the Mediterranean diet, are well-known for their association with human health, longevity, prevention of various non-communicable diseases, and sustainability. However, the excessive consumption of Ultra Processed Foods (UPFs) that replace animal-based products has the opposite effect, and information regarding the adoption of this practice within plant-based diets is essential. Excessive consumption of ultra-processed foods (UPFs) and imitation foods may diminish these benefits and even increase the risk of developing certain diseases. Therefore, it is important to raise awareness about the potential harms of UPFs and imitation products for individuals following plant-based diets [15,16,60] .

This study also had some limitations worth highlighting. As we were using only mainstream supermarkets, we were able to identify only terrestrial plant-based meat and dairy imitations. Other novel protein sources, e.g., aquatic, insects, lab-grown were not identified, which could highlight a market trend or require more targeted population sampling methodology. Another limitation is linked to the standardized nutrition and ingredient declaration made on-pack, which does not always include other nutritional components, such as fiber, vitamins, minerals, and percentages of fruits, pulses, vegetables, nuts, and oils. However, the lack of data is most likely linked to underestimation and does not pose great methodological risks and biases [61].

Using the Nutri-Score algorithm, the majority of plant-based beverages in our study were classified as Nutri-Score Category "B," in contrast to the majority of beverages in the USDA's study, which were classified as "C" [62]. The classification of "meat" products in Nutri-Score Categories differed only for plant-based alternatives to poultry meat, which were classified as "C," and poultry meat products, which were classified as "D. In contrast to the findings of Pointke M. and Pawelzik E. [63], who found lower FSAm-NPS Scores for plant-based meat alternatives compared to their animal-based equivalents in nine out of thirteen meat categories the other four did not differ significantly), our results showed no statistically significant differences in the FSAm-NPS Score for any of the four meat categories studied. The hardest part of the Nutri-Score calculation is the calculation of the Fruits, Vegetables, Nuts, Pulses, and Oils components, as described in detail in paragraph 3.6. This calculation has to be done manually and it is often linked to underestimation. Coconut cream, for example, should be scored as added fat. In general, key nutrients and information for their calculation (added sugars, trans fats, calcium, and serving size) cannot be found on-package when attempting to use other Nutrient Profiling Algorithms. The most significant and general limitation of the products concerning gaining a good Nutri-Score seemed to be the FV%.

Therefore, in relation to the validated nutrition labels currently in use, we can suggest that FOPNL can promote reformulation. New reformulations that aim for a higher FV% may result in better Nutri-Score and, consequently, a better nutritional profile, thereby attracting a larger consumer audience.

Another important finding refers to the on-pack communication of meat and dairy imitations. In line with an Australian study, where 81% of meat imitation products are sold as vegan/vegetarian [27], in Greece 82% of meat imitations and 60% of dairy imitations are sold as vegan/vegetarian. Nonetheless, meat-free and dairy-free claims are also prevalent in Greece (60% in meat imitations and 39% in dairy imitations, respectively). The primary claims made for these products concern their protein, fiber, vitamin, and mineral content. However, protein and micronutrient claims are less prevalent on the Greek market compared to other markets. Claims on fiber and allergen content (soy and gluten) are equally present in Greece as in other markets [27]. Despite the fact that the majority of products sold in Greece claim to be allergen-free, they are at the same time a "source" of other allergens. According to previous research, there are a number of potential drawbacks to using legume proteins to formulate meat imitations, like soy allergies, which is a disadvantage of using soy proteins in their formulation

Although this study did not focus on consumer preferences and attitudes, the differences in the on-pack communication seen in Greece could be indicative of differences in target consumers, beliefs, attitudes, and knowledge. It is seen that in Greece plant-based food is directly addressed to vegan/vegetarian consumers and identified with a small amount of consumers. It seems that excludes flexitarians, gluten-free eaters and/or other consumers that may limit or avoid meat and dairy products from their diet, for other reasons. As the development and progression of novel meat and dairy substitutes is dependent upon consumer perceptions and acceptance, it is necessary to identify and comprehend the stimulator factors for purchasing and consuming meat and dairy substitutes. It is important to evaluate the effects of plant-based imitations on people’s diets in order to understand if they are merely being used as a stepping stone to plant-based diets or if this trend will replace traditional models of eating. As research into the environmental and health implications of meat and dairy production increases, understanding how food-based dietary guidelines incorporate meat and dairy imitations can help to inform the development of sustainable diets. Although existing evidence suggests that adopting a plant-based diet is beneficial for health and the environment, this is based on dietary patterns that do not include such innovative products. The function of these products in modern diets should be investigated not just in terms of protein bioavailability, but also in terms of ultra-processed foods and their health effects.

References:

1. William R. AimutisNorth Carolina Food Innovation Lab, N.C.S.U.K.C.U. email: bill_aimutis@ncsu. edu Annual Review of Food Science and TechnologyPlant-Based Proteins: TheGood, Bad, and Ugly. *Annu. Rev. Food Sci. Technol. 2022* **2022**, *13*, 1–17, doi:10.1146/annurev-food-092221.
2. Sievert, K.; Lawrence, M.; Parker, C.; Baker, P. Understanding the Political Challenge of Red and Processed Meat Reduction for Healthy and Sustainable Food Systems: A Narrative Review of the Literature. *Int J Health Policy Manag* 2021, *10*, 793–808.
3. Banach, J.L.; van der Berg, J.P.; Kleter, G.; van Bokhorst-van de Veen, H.; Bastiaan-Net, S.; Pouvreau, L.; van Asselt, E.D. Alternative Proteins for Meat and Dairy Replacers: Food Safety and Future Trends. *Crit Rev Food Sci Nutr* 2022.
4. Bohrer, B.M. An Investigation of the Formulation and Nutritional Composition of Modern Meat Analogue Products. *Food Science and Human Wellness* 2019, *8*, 320–329.
5. Akhtar, S.; Ismail, T.; Layla, A.; Hussain, M.; Qamar, M. An Overview of Plant-Based Protein Rich Products. In *Plant Protein Foods*; Springer International Publishing, 2022; pp. 27–60.
6. Boukid, F. Plant-Based Meat Analogues: From Niche to Mainstream. *European Food Research and Technology* 2021, *247*, 297–308.
7. Gustafson, D.I.; Decker, E.A.; Drewnowski, A.; Hamm, M.W.; Hwang, J.; Merrigan, K.A. *Food and Agricultural Sustainability Making Healthy, Sustainable Diets Accessible and Achievable: A New Framework for Assessing the Nutrition, Environmental, and Equity Impacts of Packaged Foods*;
8. Gastaldello, A.; Giampieri, F.; de Giuseppe, R.; Grosso, G.; Baroni, L.; Battino, M. The Rise of Processed Meat Alternatives: A Narrative Review of the Manufacturing, Composition, Nutritional Profile and Health Effects of Newer Sources of Protein, and Their Place in Healthier Diets. *Trends Food Sci Technol* 2022, *127*, 263–271.
9. Aschemann-Witzel, J.; Gantriis, R.F.; Fraga, P.; Perez-Cueto, F.J.A. Plant-Based Food and Protein Trend from a Business Perspective: Markets, Consumers, and the Challenges and Opportunities in the Future. *Crit Rev Food Sci Nutr* 2020, 1–10.
10. Romão, B.; Botelho, R.B.A.; Nakano, E.Y.; Raposo, A.; Han, H.; Vega-Muñoz, A.; Ariza-Montes, A.; Zandonadi, R.P. Are Vegan Alternatives to Meat Products Healthy? A Study on Nutrients and Main Ingredients of Products Commercialized in Brazil. *Front Public Health* **2022**, *10*, doi:10.3389/fpubh.2022.900598.

11. Vlassopoulos, A.; Katidi, A.; Savvidou, T.; Kapsokefalou, M. Alignment of Nutri-Score with Mediterranean Diet Pyramid: A Food Level Analysis. *Nutrients* **2022**, *14*, doi:10.3390/nu14235097.
12. Serra-Majem, L.; Tomaino, L.; Dernini, S.; Berry, E.M.; Lairon, D.; de la Cruz, J.N.; Bach-Faig, A.; Donini, L.M.; Medina, F.X.; Belahsen, R.; et al. Updating the Mediterranean Diet Pyramid towards Sustainability: Focus on Environmental Concerns. *Int J Environ Res Public Health* **2020**, *17*, 1–20, doi:10.3390/ijerph17238758.
13. Barnard, N.D.; Goldman, D.M.; Loomis, J.F.; Kahleova, H.; Levin, S.M.; Neabore, S.; Batts, T.C. Plant-Based Diets for Cardiovascular Safety and Performance in Endurance Sports. *Nutrients* 2019, *11*.
14. Najjar, R.S.; Moore, C.E.; Montgomery, B.D. Consumption of a Defined, Plant-Based Diet Reduces Lipoprotein(a), Inflammation, and Other Atherogenic Lipoproteins and Particles within 4 Weeks. *Clin Cardiol* **2018**, *41*, 1062–1068, doi:10.1002/clc.23027.
15. Kahleova, H.; Dort, S.; Holubkov, R.; Barnard, N.D. A Plant-Based High-Carbohydrate, Low-Fat Diet in Overweight Individuals in a 16-Week Randomized Clinical Trial: The Role of Carbohydrates. *Nutrients* **2018**, *10*, doi:10.3390/nu10091302.
16. Tilman, D.; Clark, M. Global Diets Link Environmental Sustainability and Human Health. *Nature* **2014**, *515*, 518–522, doi:10.1038/nature13959.
17. King, C.W.; Webber, M.E. Water Intensity of Transportation. *Environ Sci Technol* **2008**, *42*, 7866–7872, doi:10.1021/es800367m.
18. Eshel, G.; Shepon, A.; Makov, T.; Milo, R. Land, Irrigation Water, Greenhouse Gas, and Reactive Nitrogen Burdens of Meat, Eggs, and Dairy Production in the United States. *Proc Natl Acad Sci U S A* **2014**, *111*, 11996–12001, doi:10.1073/pnas.1402183111.
19. Heller, M.C.; Keoleian, G.A. Greenhouse Gas Emission Estimates of U.S. Dietary Choices and Food Loss. *J Ind Ecol* **2015**, *19*, 391–401, doi:10.1111/jiec.12174.
20. Leroy, F.; Barnard, N.D. Children and Adults Should Avoid Consuming Animal Products to Reduce Risk for Chronic Disease: NO. *American Journal of Clinical Nutrition* **2020**, *112*, 931–936, doi:10.1093/ajcn/nqaa236.
21. Bastide, N.M.; Pierre, F.H.F.; Corpet, D.E. Heme Iron from Meat and Risk of Colorectal Cancer: A Meta-Analysis and a Review of the Mechanisms Involved. *Cancer Prevention Research* 2011, *4*, 177–184.
22. Otero, D.M.; da Rocha Lemos Mendes, G.; da Silva Lucas, A.J.; Christ-Ribeiro, A.; Ribeiro, C.D.F. Exploring Alternative Protein Sources: Evidence from Patents and Articles Focusing on Food Markets. *Food Chem* 2022, *394*.
23. Alae-Carew, C.; Green, R.; Stewart, C.; Cook, B.; Dangour, A.D.; Scheelbeek, P.F.D. The Role of Plant-Based Alternative Foods in Sustainable and Healthy Food Systems: Consumption Trends in the UK.

Science of the Total Environment **2022**, *807*, doi:10.1016/j.scitotenv.2021.151041.
24. Sabaté, J.; Soret, S. Sustainability of Plant-Based Diets: Back to the Future. In Proceedings of the American Journal of Clinical Nutrition; American Society for Nutrition, July 1 2014; Vol. 100.
25. Lima, M.; Costa, R.; Rodrigues, I.; Lameiras, J.; Botelho, G. A Narrative Review of Alternative Protein Sources: Highlights on Meat, Fish, Egg and Dairy Analogues. *Foods* 2022, *11*.
26. Pua, A.; Tang, V.C.Y.; Goh, R.M.V.; Sun, J.; Lassabliere, B.; Liu, S.Q. Ingredients, Processing, and Fermentation: Addressing the Organoleptic Boundaries of Plant-Based Dairy Analogues. *Foods* 2022, *11*.
27. Curtain, F.; Grafenauer, S. Plant-Based Meat Substitutes in the Flexitarian Age: An Audit of Products on Supermarket Shelves. *Nutrients* **2019**, *11*, doi:10.3390/nu11112603.
28. Onwezen, M.C.; Bouwman, E.P.; Reinders, M.J.; Dagevos, H. A Systematic Review on Consumer Acceptance of Alternative Proteins: Pulses, Algae, Insects, Plant-Based Meat Alternatives, and Cultured Meat. *Appetite* 2021, *159*.
29. Loveday, S.M. Plant Protein Ingredients with Food Functionality Potential. *Nutr Bull* 2020, *45*, 321–327.
30. Mayer Labba, I.C.; Steinhausen, H.; Almius, L.; Bach Knudsen, K.E.; Sandberg, A.S. Nutritional Composition and Estimated Iron and Zinc Bioavailability of Meat Substitutes Available on the Swedish Market. *Nutrients* **2022**, *14*, doi:10.3390/nu14193903.
31. Cutroneo, S.; Angelino, D.; Tedeschi, T.; Pellegrini, N.; Martini, D. Nutritional Quality of Meat Analogues: Results From the Food Labelling of Italian Products (FLIP) Project. *Front Nutr* **2022**, *9*, doi:10.3389/fnut.2022.852831.
32. Craig, W.J.; Mangels, A.R.; Brothers, C.J. Nutritional Profiles of Non-Dairy Plant-Based Cheese Alternatives. *Nutrients* **2022**, *14*, doi:10.3390/nu14061247.
33. Drewnowski, A. Most Plant-Based Milk Alternatives in the USDA Branded Food Products Database Do Not Meet Proposed Nutrient Standards or Score Well on Nutrient Density Metrics. *Nutrients* **2022**, *14*, 4767, doi:10.3390/nu14224767.
34. Ložnjak Švarc, P.; Jensen, M.B.; Langwagen, M.; Poulsen, A.; Trolle, E.; Jakobsen, J. Nutrient Content in Plant-Based Protein Products Intended for Food Composition Databases. *Journal of Food Composition and Analysis* **2022**, *106*, doi:10.1016/j.jfca.2021.104332.
35. Lähteenmäki-Uutela, A.; Rahikainen, M.; Lonkila, A.; Yang, B. Alternative Proteins and EU Food Law. *Food Control* **2021**, *130*, 108336, doi:10.1016/j.foodcont.2021.108336.

36. Ismail, I.; Hwang, Y.H.; Joo, S.T. Meat Analog as Future Food: A Review. *J Anim Sci Technol* 2020, *62*, 111–120.
37. CELEX_32010R0066_EN_TXT.
38. Kaur, A.; Scarborough, P.; Rayner, M. A Systematic Review, and Meta-Analyses, of the Impact of Health-Related Claims on Dietary Choices. *International Journal of Behavioral Nutrition and Physical Activity* 2017, *14*.
39. Katidi, A.; Vlassopoulos, A.; Kapsokefalou, M. Development of the Hellenic Food Thesaurus (HelTH), a Branded Food Composition Database: Aims, Design and Preliminary Findings. *Food Chem* **2021**, *347*, doi:10.1016/j.foodchem.2021.129010.
40. Katidi, A.; Vlassopoulos, A.; Xanthopoulou, S.; Boutopoulou, B.; Moriki, D.; Sardeli, O.; Rufián-Henares, J.Á.; Douros, K.; Kapsokefalou, M. The Expansion of the Hellenic Food Thesaurus; Allergens Labelling and Allergens-Free Claims on Greek Branded Food Products. *Nutrients* **2022**, *14*, doi:10.3390/nu14163421.
41. Katidi, A.; Pavlopoulou, A.; Vlassopoulos, A.; Kapsokefalou, M. The Nutritional Composition of Natural and Organic Branded Food Products: A Cross-Sectional Analysis of the Greek Foodscape. *Nutrients* **2022**, *14*, doi:10.3390/nu14040808.
42. Volpe, R.; Maggi, S. *Nutrition Labelling: We Need a New European Algorithm*; 2020; Vol. 1;.
43. Hagmann, D.; Siegrist, M. Nutri-Score, Multiple Traffic Light and Incomplete Nutrition Labelling on Food Packages: Effects on Consumers' Accuracy in Identifying Healthier Snack Options. *Food Qual Prefer* **2020**, *83*, doi:10.1016/j.foodqual.2020.103894.
44. Katidi, A.; Xypolitaki, K.; Vlassopoulos, A.; Kapsokefalou, M. Nutritional Quality of Plant-Based Meat and Dairy Imitation Products and Comparison with Animal-Based Counterparts. *Nutrients* **2023**, *15*, 401, doi:10.3390/nu15020401.
45. Vlassopoulos, A.; Katidi, A.; Kapsokefalou, M. Performance and Discriminatory Capacity of Nutri-Score in Branded Foods in Greece. *Front Nutr* **2022**, *9*, doi:10.3389/fnut.2022.993238.
46. de Bauw, M.; Matthys, C.; Poppe, V.; Franssens, S.; Vranken, L. A Combined Nutri-Score and 'Eco-Score' Approach for More Nutritious and More Environmentally Friendly Food Choices? Evidence from a Consumer Experiment in Belgium. *Food Qual Prefer* **2021**, *93*, doi:10.1016/j.foodqual.2021.104276.
47. *Update of the Nutri-Score Algorithm*;
48. Ireland, J.; Møller, A. What's New in LanguaL™? *Procedia Food Sci* **2013**, *2*, 117–121, doi:10.1016/j.profoo.2013.04.018.
49. The Food Classification and Description System FoodEx 2 (Draft-revision 1). *EFSA Supporting Publications* **2011**, *8*, doi:10.2903/sp.efsa.2011.EN-215.

50. Romão, B.; Botelho, R.B.A.; Nakano, E.Y.; Raposo, A.; Han, H.; Vega-Muñoz, A.; Ariza-Montes, A.; Zandonadi, R.P. Are Vegan Alternatives to Meat Products Healthy? A Study on Nutrients and Main Ingredients of Products Commercialized in Brazil. *Front Public Health* **2022**, *10*, 1565, doi:10.3389/FPUBH.2022.900598/BIBTEX.
51. Cole, E.; Goeler-Slough, N.; Cox, A.; Nolden, A. Examination of the Nutritional Composition of Alternative Beef Burgers Available in the United States. *Int J Food Sci Nutr* **2022**, *73*, 425–432, doi:10.1080/09637486.2021.2010035.
52. Ahmad, M.; Qureshi, S.; Akbar, M.H.; Siddiqui, S.A.; Gani, A.; Mushtaq, M.; Hassan, I.; Dhull, S.B. Plant-Based Meat Alternatives: Compositional Analysis, Current Development and Challenges. *Applied Food Research* 2022, *2*.
53. Cole, E.; Goeler-Slough, N.; Cox, A.; Nolden, A. Examination of the Nutritional Composition of Alternative Beef Burgers Available in the United States. *Int J Food Sci Nutr* **2022**, *73*, 425–432, doi:10.1080/09637486.2021.2010035.
54. Curtain, F.; Grafenauer, S. Plant-Based Meat Substitutes in the Flexitarian Age: An Audit of Products on Supermarket Shelves. *Nutrients* **2019**, *11*, doi:10.3390/NU11112603.
55. Calvo-Lerma, J.; Crespo-Escobar, P.; Martínez-Barona, S.; Fornés-Ferrer, V.; Donat, E.; Ribes-Koninckx, C. Differences in the Macronutrient and Dietary Fibre Profile of Gluten-Free Products as Compared to Their Gluten-Containing Counterparts. *Eur J Clin Nutr* **2019**, *73*, 930–936, doi:10.1038/S41430-018-0385-6.
56. Angelino, D.; Rosi, A.; Vici, G.; Russo, M. dello; Pellegrini, N.; Martini, D. Nutritional Quality of Plant-Based Drinks Sold in Italy: The Food Labelling of Italian Products (FLIP) Study. *Foods* **2020**, *9*, doi:10.3390/FOODS9050682.
57. Drewnowski, A. Most Plant-Based Milk Alternatives in the USDA Branded Food Products Database Do Not Meet Proposed Nutrient Standards or Score Well on Nutrient Density Metrics. *Nutrients* **2022**, *14*, 4767, doi:10.3390/NU14224767.
58. Craig, W.J.; Mangels, A.R.; Brothers, C.J. Nutritional Profiles of Non-Dairy Plant-Based Cheese Alternatives. *Nutrients* **2022**, *14*, doi:10.3390/NU14061247.
59. Shaghaghian, S.; McClements, D.J.; Khalesi, M.; Garcia-Vaquero, M.; Mirzapour-Kouhdasht, A. Digestibility and Bioavailability of Plant-Based Proteins Intended for Use in Meat Analogues: A Review. *Trends Food Sci Technol* 2022, *129*, 646–656.
60. Monteiro, C.A.; Astrup, A. Does the Concept of "Ultra-Processed Foods" Help Inform Dietary Guidelines, beyond Conventional Classification Systems? YES. *Am J Clin Nutr* **2022**, doi:10.1093/ajcn/nqac122.

61. Vlassopoulos, A.; Katidi, A.; Kapsokefalou, M. Performance and Discriminatory Capacity of Nutri-Score in Branded Foods in Greece. *Front Nutr* **2022**, *9*, 2359, doi:10.3389/FNUT.2022.993238/BIBTEX.
62. Drewnowski, A. Perspective: Identifying Ultra-Processed Plant-Based Milk Alternatives in the USDA Branded Food Products Database. *Advances in Nutrition* **2021**, *12*, 2068–2075, doi:10.1093/advances/nmab089.
63. Pointke, M.; Pawelzik, E. Plant-Based Alternative Products: Are They Healthy Alternatives? Micro- and Macronutrients and Nutritional Scoring. *Nutrients* **2022**, *14*, doi:10.3390/nu14030601.

APPENDIX 1; HelTH's Classification System

Food Category	Food Subcategory	Food Group	Food subgroup	LanguaL code
01. Milk, Milk Product or Milk Substitute	1.Milk	1. Fresh		A0780
		2. UHT		
		3. Long lasting		A0781
		4. Evaporated		
		5. Chocolate		
		6. Fermented		A0783
	0. Cream	1. Milk cream		A0782
		2. Whipped cream		
	2. Yogurt	1. White		A0783
		2. Dessert		
		3. Traditional		
		4. Strained		
		5. Beverage		
		6. For kids		
		7. Kefir		
	3. Cheese	1. Cured	1. Feta and white cheese	A0785
			2. Gruyere, kefalotyri and similar cheese	
			3. Parmesan and similar cheese	

			4. Regato and other hard cheese	
			5. Semi-hard cheese	
			6. Blue cheese	
			7. Sliced cheese	
			8. Grated cheese	
			9. Mini cheese in portions	
			0. Delicatessen	
		2. Uncured	0. Delicatessen	A0786
			1. Cream cheese	
			2. Mozzarella	
		3. Processed		A0787
	4. Imitation milk products	1. Plant-based beverage		A0824
		2. Plant- based dessert		
		3.Plant-based cheese		
	5. Frozen dairy desserts	1. Ice cream		A0789
		2. Other		

02. Egg or egg product	1. Fresh or processed egg	1. Fresh eggs		A0791
		2. Processed eggs		
	2. Egg dish			A0792

03. Meat or meat product	1. Red meat	1. Calf		A0794
		2. Pork		
		3. Lamp		
		4. Kid		
		5. Sheep		
		6. Hare		
	2. Poultry meat	1. Chicken		A0795
		2. Turkey		
		3. Other		
	3. Offal			A0796
	4. Preserved meat	1. Ham		A0797
		2. Turkey-chicken		
		3.Shoulder-length salami		
		4. Pariza		
		5. Salami		
		6. Mortadelo		
		7. Bacon		
		8. Delicatessen		
		9. Set salami-cheese		
		0. Canned meat		

	5. Sausage or similar meat product	1. Sausage		A0798
		2. Pate		
		3. Other		
	6. Meat dish	1. Red and similar meat		A0799
		2. Poultry		
	7. Meat analogue			A0800

04. Seafood or related product	1. Seafood or related organism	1. Fish		A0802
		2. Mollusks		
		3. Crustaceans		
	2. Seafood product	1. Frozen fishsticks		A0803
		2. Canned	1. Tuna	
			2. Sardines	
			3. Other processed fish	
			4. Mollusks	
		3. Smoked fish		
		4. Salted fish		
		5. Fish eggs		
		6. Other		
		7. Seafood dish		A0804

05. Fat or oil	1. Vegetable fat or oil	1. Vegetable fat		A0806
		2. Vegetable oil	1. Olive oil	
			2. Corn oil	
			3. Sunflower oil	
			4. Seed oil	
			5. Other oil	
	2. Margarine or lipid of mixed origins	1. Margarine		A0807
		2. Lipid of mixed origin		
	3. Butter or other animal fat	1. Butter		A0809
		2. Other animal fats		A0810
		3. Fish oils		A0811

06. Grain or grain product	1. Cereal or cereal-like milling products and derivatives	1. Fresh doughs and leaves		A0813
		2. Frozen leaves		
		3. Flour		
		4. Semolina		
		5. Other		
	2. Rice or other grain	1 White rice		A0814
		2. Parboiled rice		

		3. Basmati rice		
		4. Other rice		
		5. Noodles		
		6. Ready-to-eat recipes		
	3. Pasta and similar products	1. Macaroni		A0815
		2. Other pasta		
		3. Filled macaroni		
		4. Traditional pasta		
		5. Fresh pasta		
	4. Breakfast cereals	1. Corn flakes		A0816
		2. Muesli		
		3. For adults		
		4. For kids		
		5. Oats		
		0. Cereal bars		A1330
	5. Bread and similar products	1. Leavened bread	1. Wheat bread	A0818
			2. Rye-wholemeal bread	
			3. Other	
		2. Unleavened bread	1. Wheat toast bread	A0819
			2. Wholemeal toast bread	
			3. Pitta and mini bread	
			4. Wheat rusks	
			5. Rye-wholemeal rusks	
			6. Barley rusks	

			7. Mini rusks-snacks	
			8. Other	
		3. Bread product	0. Breadsticks	A0820
			1. Crackers	
			2. Wheat toast	
			3. Rye-wholemeal toast	
			4. Breadcrumbs	
			5. Croutons	
			6. Other	
	6. Fine bakery ware	1. Biscuits, sweet and semi-sweet	1. Biscuits	A1331
			2. Cookies	
			3. Multi-cereal	
			4. Digestive	
			5. Wafers	
			6. Sweet buns	
		2. Waffles and pancakes	1. Waffles	A1297
			2. Pancakes	
		3. Pastries and cakes	1. Cakes	A1332
			2. Doughnut	
			3. Croissant	
			4. Brioche	
		4. Sweetened pie		A1334
		5. Ready-to-eat sweet crepes		A0821

		6. Pantyhose bases and other confectionery ingredients		
	7. Savoury cereal dish	1. Pie, unsweetened or pizza	1. Pizza	A1296
			2. Pianirli, calzone and other	
			3. Savoury pie	
		2. Pasta dish		A1204
		3. Others (spring rolls, crepes etc.)		A0822

07. Nut, seed or kernel	0. Nuts			A0823
	1. Seeds and kernels	1. Olives and olive paste		
		2. Other		
	2. Nut or seed product	1. Tahini paste		A0824
		2. Peanut butter		
		3. Other nut pastes		

08. Vegetable or vegetable product	1. Vegetable (excluding potato)	0. Frozen vegetable		A0826
		1. Vegetable product	1. Chopped tomato	A0827

			2. Passata	
			3. Clogged tomato	
			4. Tomato paste	
			5. Other processed vegetable	
			6. Vegetable dish	A0828
			7. Mushroom dish	A1335
	2. Starchy root or potato	0. Frozen potato		A0829
		1. Mashed potato		
		2. Other		
		3. Potato dish		A0830
	3. Pulse or pulse product	1. Beans		A0831
		2. Lentils		
		3. Chickpeas		
		4. Kinoa		
		5. Other pulse		
		6. Pulse dish		A0832

09. Fruit or fruit product	0. Fruit			A0833
	1. Processed food product	1. Dried fruits		A0834
		2. Fruit compotes		

		3. Other		

10. Sugar or sugar product	1. Sugar, honey or syrup	1. Sugar	1. White	A0836
			2. Brown	
			3. Fructose	
			4. Sugar substitutes	
			5. Other (molasses, petimezi etc.)	
		2. Honey	0. Simple	
			1. With flavors	
			2. Royal jelly	
		3. Syrup		
	2. Jam or marmalade	1. Peach-apricot		A0837
		2. Strawberry-cherry		
		3. Other flavor		
		4. With no added sugar		
		5. Candied fruit		
		0. Fruit jelly		
	3.Non-chocolate confectionery or other sugar product	1. Loukoumi		A0838
		2. Sesame bar		
		3. Sweet preserve		

		4. Mastic		
		5. Halva		
		6. Other		
	4. Chocolate or chocolate product	1. Dark chocolate		A0839
		2. Milk chocolate		
		3. White chocolate		
		4.Filled with nuts chocolate		
		5. For kids chocolate		
		6. Mini chocolate		
		7. Chocolate bars		
		8. Other chocolate		
		9. Hazelnut praline		
		0. Chocolate kouvertura		

11. Beverage (Non-milk)	1. Juice or nectar	1. Fresh juice		A0841
		2. Nectar		
		3. Concentrated		
		4. Refrigerated		
	2. Non-alcoholic beverage	1. Soft drinks	1. Coca cola	A0843
			2. Gazoza	

			3. Lemonade	
			4. Orangade	
			5. Soda	
			6. Tonic and other	
			7. Energy drinks	
		2. Water	1. Water	A0844
			2. Carbonated mineral water	
			3. Still mineral water	
		3. Coffee, tea, cocoa or infusion	1. Coffee	A0845
			2. Tea	
			3. Cocoa powder	
			4. Chocolate powder	
			5. Other infusion	
	3. Alcoholic beverage	1. Beer or beer-like beverage		A0847
		2. Cider, perry or similar drink		A0848
		3. Wine, fortified wine or wine-like beverage		A0849
		4. Liqueur or spirits		A0850
		5. Alcoholic mixed drink		A0851

		1.Baking ingredient	1. Yeast	A0854

12. Miscellaneous food product	1. Spice, condiment or other ingredient		2. Corn flower	
			3. Baking powder	
			4. Pectin	
			5. Zelatin	
			6. Additives	
			7. Others	
		2. Flavoring or essence	1.Vanilla essence	A0855
			2. Other essence	
			3. Other	
		3. Seasoning or extract	1. Salt	A0856
			2. Cubes	
			3. Broths	
			4. Gravy thickener	
			5. Beef extract	
			6. Mixtures for meat	
			7. Other savoury mixtures	
			8. Mixtures for sweets	
			9. Other	
		4. Herb or spice	1. Herbs	A0857
			2. Spices	
			3. Other	
		5. Condiment	1. Mustard	A0858
			2. Ketchup	
			3. Barbeque sauce	

			4. Soy sauce	
			5. Tabasco sauce	
			6. Other sauce	
		6. Dressing, mayonnaise	1. Mayonnaise	A0859
			2. Other dressings	
			3.Pickle or chutney	A0860
	2. Prepared food product	1. Savoury sauce	1. Bechamel	A0862
			2. Others	
		2. Dessert sauce	1. Fruit sauce	A0863
			2. Fudge sauce	
			3. Brandy sauce	
			4. Others	
		3. Dessert	1. Wheat cream	A0864
			2. Rice pudding	
			3. Dessert with chocolate	
			4. Other dessert	
		4. Soup	1. Ready-to-eat soup	A0865
			2. Other	
		5. Prepared salad	1. Egg salad	A0866
			2. Tuna salad	
			3. Chicken salad	
			4. Tzatziki	
			5. Cheese-based salad	
			6. Vegetable-based salad	

			7. Other salads	
		6. Sandwich filling	1. Cheese-based filling	A0867
			2. Fish-based filling	
			3. Meat-based filling	
			4. Other filling	
		7. Savoury snacks	1. Potato chips	A0868
			2. Other chips	
			3. Popcorn	
			4. Rice wafers	
			5. Other savoury snack	
		8. Sandwich		A1203

13. Product for special nutritional use or dietary supplement	1. Dietary supplement			A0870
	2. Food for special nutritional use	1. Medical food		A0872
		2. Food for infants		A0873
		3. Food for weight reduction		A1205
		4. Sports food		A1206

APPENDIX 2: Complementary questionnaire

Η συμπεριφορά του καταναλωτή σχετικά με τα φυτικής προέλευσης τρόφιμα και τη διατροφή στην Ελλάδα

Η έρευνα αυτή διεξάγεται στα πλαίσια εκπόνησης διπλωματικής εργασίας του μεταπτυχιακού τίτλου σπουδών «Τρόφιμα, Διατροφή και Υγεία» του Γεωπονικού Πανεπιστημίου Αθηνών. Σκοπός της είναι να διερευνηθεί η καταναλωτική συμπεριφορά των Ελλήνων σχετικά με τα φυτικής προέλευσης τρόφιμα. Μέσω της έρευνας γίνεται μια πρώτη προσπάθεια να καταγραφεί το επίπεδο κατανόησης και ο βαθμός εξοικείωσης βασικών εννοιών που αφορούν τη διατροφή βασισμένη σε φυτικής προέλευσης τρόφιμα, ένα θέμα που δεν είναι ευρέως διαδεδομένο στο Ελληνικό κοινό. Η συμβολή σας στην διεξαγωγή της έρευνας είναι ιδιαίτερα σημαντική. Το ερωτηματολόγιο είναι ανώνυμο και τα αποτελέσματα θα χρησιμοποιηθούν αυστηρά και μόνο στα πλαίσια της στατιστικής ανάλυσης. Ο χρόνος που θα χρειαστείτε για την συμπλήρωση του ερωτηματολογίου είναι περίπου δέκα λεπτά.

Σας ευχαριστώ πολύ εκ των προτέρων για τη συμβολή και τον χρόνο σας.

Με εκτίμηση,
Ξυπολιτάκη Κωνσταντίνα

ΕΡΩΤΗΣΕΙΣ

1. Ποια από τις παρακάτω δηλώσεις περιγράφει τις διατροφικές σας συνήθειες;

- ☐ Καταναλώνω συχνά κρέας, όπως μοσχάρι, χοιρινό, κοτόπουλο, γαλοπούλα, ψάρι και/ή οστρακοειδή (Omnivore)
- ☐ Μερικές φορές τρώω κρέας, αλλά προσπαθώ να μειώσω την κατανάλωσή του και συχνά επιλέγω τροφές φυτικής προέλευσης (Flexitarian)
- ☐ Τρώω ψάρια και/ή οστρακοειδή, αλλά όχι άλλα είδη κρέατος (Pescetarian)
- ☐ Δεν τρώω κρέας και ψάρι κανενός είδους, αλλά τρώω αυγά ή/και γαλακτοκομικά προϊόντα (Vegetarian)
- ☐ Δεν τρώω κρέας, ψάρι, αυγά, γαλακτοκομικά προϊόντα ή άλλα ζωικά συστατικά (Vegan)
- ☐ Άλλο:

2. Πόσο καιρό ακολουθείτε τις συγκεκριμένες διατροφικές συνήθειες;

- ☐ Λιγότερο από 6 μήνες
- ☐ 6 μήνες έως 2 έτη
- ☐ 2 έως 5 χρόνια
- ☐ Πάνω από 5 χρόνια

3. Τι σημαίνει για σας **φυτική διατροφή** (Plant Based Nutrition); :

- ☐ Διατροφή που βασίζεται στη Μεσογειακή. Περιέχει λαχανικά, όσπρια, φρούτα , δημητριακά και φυσικές τροφές φυτικής προέλευσης.
- ☐ Φυτική διατροφή που βασίζεται κυρίως σε επεξεργασμένες τροφές φυτικής προέλευσης, Περιλαμβάνει απομιμήσεις κρέατος (υποκατάστατο κρέατος), γαλακτοκομικών προϊόντων (υποκατάστατο γαλακτοκομικών π.χ ρόφημα αμυγδάλου), αρτοσκευάσματα που δεν περιέχουν γαλακτοκομικά προϊόντα ή/και ζυμαρικά με βάση τα όσπρια κ.ά.
- ☐ Συνδυασμός των παραπάνω

4. Ποιος βαθμός περιγράφει καλύτερα την συχνότητα που καταναλώνετε τα ακόλουθα τρόφιμα τους τελευταίους 12 μήνες;

	1=Ποτέ	2=1-3 φορές τον μήνα	3=1 φορά την εβδομάδα	4= πάνω από 1 φορά την εβδομάδα	5= Τουλάχιστον μία φορά την μέρα
Βοδινό					
Κοτόπουλο/ Γαλοπούλα					
Ψάρι/Θαλασσινά					
Γάλα					
Γιαούρτι					
Τυρί					
Παγωτό					
Αβγά					

5. Σε σύγκριση με ένα χρόνο πριν, πόσο κρέας ή γαλακτοκομικά (π.χ. βοδινό, χοιρινό, κοτόπουλο, ψάρι, γάλα, τυρί, κτλ) τρώτε τώρα;

- ☐ Πολύ λιγότερο
- ☐ Λίγο λιγότερο
- ☐ Καμία αλλαγή
- ☐ Λίγο περισσότερο
- ☐ Πολύ περισσότερο

6. Σκοπεύετε να αυξήσετε ή να μειώσετε την κατανάλωση των **κρέατος** τους επόμενους 6 μήνες;

- ☐ θα καταναλώνω πιο λίγο
- ☐ Θα καταναλώνω λίγο λιγότερο
- ☐ Θα καταναλώνω περίπου το ίδιο
- ☐ Θα καταναλώσω λίγο παραπάνω
- ☐ Θα καταναλώνω περισσότερο

7. Σκοπεύετε να αυξήσετε ή να μειώσετε την κατανάλωση των **γαλακτοκομικών** προϊόντων τους επόμενους 6 μήνες;

- ☐ θα καταναλώνω πιο λίγο
- ☐ Θα καταναλώνω λίγο λιγότερο
- ☐ Θα καταναλώνω περίπου το ίδιο
- ☐ Θα καταναλώσω λίγο παραπάνω
- ☐ Θα καταναλώνω περισσότερ

8. Σημειώστε πόσο διαφωνείτε ή συμφωνείτε με καθεμία από τις ακόλουθες δηλώσεις σχετικά με τις υποθέσεις σας σχετικά με την κατανάλωση κρέατος

*Ως προϊόν υποκατάστασης εννοείται η απομίμηση του συμβατικού προϊόντος με κύριο συστατικό συνήθως τις φυτικές πηγές πρωτεΐνης

(1.Διαφωνώ κάθετα 2.Διαφωνώ 3.Ουδέτερος 4.Συμφωνώ 5.Συμφωνώ απόλυτα)

Έχω σκεφτεί να αντικαταστήσω το κρέας με τα νέα υποκατάστατα που υπάρχουν στην αγορά					
Τα φυτικής προέλευσης τρόφιμα είναι πιο ακριβά σε σχέση με αυτά της ζωϊκής.					
Έχω σκεφτεί να αντικαταστήσω τα γαλακτοκομικά με τα νέα υποκατάστατα που κυκλοφορούν στην αγορά					
Η ζωική πρωτεΐνη είναι πιο ακριβή σε σχέση με την φυτικής προέλευσης πρωτεΐνη					
Δεν θέλω να αλλάξω τις διατροφικές μου συνήθειες ή τη ρουτίνα					
Τα τρόφιμα φυτικής προέλευσης δεν θα ήταν αρκετά χορταστικά					
Δεν θέλω οι άνθρωποι να πιστεύουν ότι είμαι δύσκολος ή πολύ εναλλακτικός.					
Νομίζω ότι οι άνθρωποι προορίζονται να τρώνε τρόφιμα με βάση τα ζώα					
Δεν θα έπαιρνα αρκετή ενέργεια ή δύναμη από τρόφιμα φυτικής προέλευσης					
Τα τρόφιμα φυτικής προέλευσης δεν θα ήταν αρκετά νόστιμα.					
Θα χρειαστεί να φάω μεγάλη ποσότητα φυτικών τροφών για να νιώσω χορτάτος.					
Τα φυτικά τρόφιμα φαίνονται πολύ ασυνήθιστα.					
Δεν υπάρχει αρκετή επιλογή σε τρόφιμα φυτικής προέλευσης όταν τρώω έξω.					
Δεν ξέρω τι να φάω αντί για πολλά κρέατα με βάση τα ζώα					
Τα τρόφιμα φυτικής προέλευσης δεν είναι βολικά					
Η οικογένειά μου/ο σύντροφός μου δεν θα τρώει τρόφιμα φυτικής προέλευσης.					

Χρειάζεται πολύς χρόνος για την προετοιμασία γευμάτων φυτικής προέλευσης τρόφιμα.					
Κάποιος άλλος αποφασίζει για το μεγαλύτερο μέρος του φαγητού που τρώω					
Τα φυτικά τρόφιμα που θα χρειαζόμουν δεν είναι διαθέσιμα εκεί που ψωνίζω ή τρώω έξω.					
Δεν ξέρω πώς να ετοιμάζω γεύματα με βάση στα τρόφιμα φυτικής προέλευσης.					
Δεν υπάρχουν αρκετά θρεπτικά συστατικά στα τρόφιμα φυτικής προέλευσης.					
Δεν υπάρχει αρκετή πρωτεΐνη στα τρόφιμα φυτικής προέλευσης					
Θα ανησυχούσα για την υγεία μου (εκτός από σίδηρο και πρωτεΐνη) αν έτρωγα μόνο φυτικά τρόφιμα					
Θα είχα δυσπεψία, φούσκωμα, αέρια ή μετεωρισμό όταν έτρωγα φυτικά τρόφιμα					
Τα γεύματα με βάση την φυτική προέλευση ή τα σνακ δεν είναι διαθέσιμα όταν τρώω έξω.					
Τα τρόφιμα φυτικής προέλευσης είναι πολύ ακριβά.					

9. Σε σύγκριση με ένα χρόνο πριν, τρώτε περισσότερο ή λιγότερο φυτικά τρόφιμα;

   - ☐ Πολύ λιγότερο
   - ☐ Λίγο λιγότερο
   - ☐ Καμία αλλαγή
   - ☐ Λίγο περισσότερο
   - ☐ Πολύ περισσότερο

10. Έχετε δοκιμάσει τα υποκατάστατα κρέατος (Γύρος, μπιφτέκια, κοτομπουκιές φυτικής πρωτεΐνης κ.α) ;

- ☐ Ναι
- ☐ Όχι

11. Έχετε δοκιμάσει τα υποκατάστατα γαλακτοκομικών προϊόντων (Ροφήματα φυτικών καρπών, επιδόρπια γιαουρτιού φυτικών καρπών, φυτικά τυριά, παγωτά κ.ά) ;

   - ☐ Ναι

- ☐ Όχι

12. Σκοπεύετε να αυξήσετε ή να μειώσετε την κατανάλωση των **υποκατάστατων κρέατος** τους επόμενους 6 μήνες;

    - ☐ Θα καταναλώνω λιγότερο
    - ☐ Θα καταναλώνω λίγο λιγότερο
    - ☐ Θα καταναλώνω περίπου το ίδιο
    - ☐ Θα καταναλώσω λίγο παραπάνω
    - ☐ Θα καταναλώνω περισσότερο

13. Σκοπεύετε να αυξήσετε ή να μειώσετε την κατανάλωση **υποκατάστατων γαλακτοκομικών** τους επόμενους 6 μήνες;

    - ☐ Θα καταναλώνω λιγότερο
    - ☐ Θα καταναλώνω λίγο λιγότερο
    - ☐ Θα καταναλώνω περίπου το ίδιο
    - ☐ Θα καταναλώσω λίγο παραπάνω
    - ☐ Θα καταναλώνω περισσότερο

14. Ποια από τις παρακάτω εναλλακτικές πρωτεΐνες εμπιστεύεστε περισσότερο; Κατατάξτε τα από το 1 (με τη μεγαλύτερη εμπιστοσύνη) έως το 5 (να εμπιστεύεστε τη λιγότερο).

    - ☐ Πρωτεΐνη φυτικής προέλευσης (συμπεριλαμβανομένων δημητριακών, οσπρίων)
    - ☐ Μύκητες (π.χ. διάφορα είδη μανιταριών, μαγιά)
    - ☐ Πρωτεΐνη με βάση τα φύκια
    - ☐ Πρωτεΐνη με βάση την κυτταροκαλλιέργεια (π.χ. καλλιεργημένο κρέας, γαλακτοκομικά -cultivated meat κ.λπ.)
    - ☐ Πρωτεΐνη με βάση τα έντομα

15. Ποιά από τα παρακάτω θα θέλατε να έχετε ως κύρια συστατικά σε επεξεργασμένα φυτικά τρόφιμα (επιλέξτε έως 5);

    - ☐ Ρύζι
    - ☐ Φακές
    - ☐ Αμύγδαλα
    - ☐ Ρεβύθια
    - ☐ Φασόλια
    - ☐ Αρακάς
    - ☐ Μανιτάρια
    - ☐ Βρώμη
    - ☐ Φουντούκια

- ☐ Ηλιόσποροι
- ☐ Κάσιους
- ☐ Σπόροι κολοκύθας
- ☐ Σόγια
- ☐ Καρύδα
- ☐ Κινόα
- ☐ Σπόροι κάνναβης
- ☐ Φάβα
- ☐ Σπιρουλίνα
- ☐ Κανένα

16. Θεωρείτε ότι είναι εύκολη η εύρεση των (προσβασιμότητα) υποκατάστατων κρέατος στα καταστήματα τροφίμων ;

- ☐ Ναι
- ☐ Όχι
- ☐ Ίσως

17. Από τα παρακάτω υποκατάστατα κρέατος, ποια είναι αυτά που συναντάτε πιο συχνά στα καταστήματα τροφίμων;

- ☐ Φυτικής προέλευσης αλλαντικά *π.χ. Σαλάμι, ζαμπόν φέτες
- ☐ Φυτικής προέλευσης μπιφτέκια
- ☐ Φυτικής προέλευσης κιμάς
- ☐ Φυτικής προέλευσης λουκάνικα
- ☐ Φυτικής προέλευσης κεφτεδάκια
- ☐ Φυτικής προέλευσης σνίτσελ/ κοτομπουκιές
- ☐ Φυτικής προέλευσης κεμπάπ
- ☐ Φυτικής προέλευσης γύρος
- ☐ Φυτικής προέλευσης ψάρι
- ☐ Φυτικής προέλευσης αβγό
- ☐ Άλλο

18. Θεωρείτε ότι είναι εύκολη η πρόσβαση στα υποκατάστατα γαλακτοκομικών προϊόντων ;

- ☐ Ναι
- ☐ Όχι
- ☐ Ίσως

19. Ποια από τα παρακάτω υποκατάστατα γαλακτοκομικών συναντάτε πιο συχνά στα καταστήματα τροφίμων:

- ☐ υποκατάστατα γάλακτος
- ☐ υποκατάστατα γιαουρτιού
- ☐ υποκατάστατο παγωτού
- ☐ υποκατάστατα τυριού

20. Θεωρείτε ότι είναι εύκολη η πρόσβαση στα φυτικής προέλευσης αρτοσκευάσματα/ζυμαρικά;

- ☐ Ναι
- ☐ Όχι
- ☐ Ίσως

21. Δεδομένου ότι τα **υποκατάστατα κρέατος** έχει την ίδια γεύση και υφή με το κρέας ζωικής προέλευσης.

Πόσο πιθανό είναι να τρώτε κρέας φυτικής προέλευσης αντί για κρέας;

- ☐ Καθόλου πιθανό
- ☐ Κάπως πιθανό
- ☐ Μέτρια πιθανή
- ☐ Πολύ πιθανό
- ☐ Εξαιρετικά πιθανό

Να πληρώσετε υψηλότερη τιμή για το υποκατάστατο κρέατος από το κρέας ζωικής προέλευσης;

- ☐ Καθόλου πιθανό
- ☐ Λίγο
- ☐ Μέτρια πιθανό
- ☐ Πολύ πιθανό
- ☐ Εξαιρετικά πιθανό

22. Δεδομένου ότι τα **υποκατάστατα τυριού/ γαλακτοκομικών προϊόντων** και έχει την ίδια γεύση και υφή με τα συμβατικά τυροκομικά προϊόντα.

Πόσο πιθανό είναι να τρώτε προϊόντα τυριού φυτικής προέλευσης αντί για συμβατικά τυροκομικά προϊόντα;

- ☐ Καθόλου πιθανό
- ☐ Κάπως πιθανό
- ☐ Μέτρια πιθανή
- ☐ Πολύ πιθανό
- ☐ Εξαιρετικά πιθανό

Να πληρώσετε υψηλότερη τιμή για τα υποκατάστατα γαλακτοκομικών προϊόντων από ό,τι για τα συμβατικά γαλακτοκομικά προϊόντα;

- ☐ Καθόλου πιθανό
- ☐ Λίγο
- ☐ Μέτρια πιθανό
- ☐ Πολύ πιθανό
- ☐ Εξαιρετικά πιθανό

23. Δεδομένου ότι τα προϊόντα **αρτοποιίας** (π.χ. ψωμί ή μπισκότα χωρίς αυγά ή βούτυρο) και **ζυμαρικά** έχουν ακριβώς την ίδια γεύση και υφή με τα συμβατικά προϊόντα αρτοποιίας.

Πόσο πιθανό είναι να τρώτε υποκατάστατα προϊόντα αρτοποιίας αντί για συμβατικά προϊόντα αρτοποιίας;

- ☐ Καθόλου πιθανό
- ☐ Κάπως απίθανο
- ☐ Μέτρια πιθανή
- ☐ Κάπως πιθανό
- ☐ Πολύ πιθανό

Να πληρώσετε υψηλότερη τιμή για τα **υποκατάστατα προϊόντων αρτοποιίας** και **εναλλακτικά ζυμαρικά** από ό,τι για τα συμβατικά αρτοσκευάσματα;

- ☐ Καθόλου πιθανό
- ☐ Λίγο
- ☐ Μέτρια πιθανό
- ☐ Πολύ πιθανό
- ☐ Εξαιρετικά πιθανό

24. Ηλικία

- ☐ 16-18
- ☐ 19-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ 65+

25. Ποιο από αυτά περιγράφει καλύτερα τον τόπο διαμονής σας;

- ☐ Πόλη
- ☐ Προάστιο πόλης
- ☐ Αγροτική - έξω από μια πόλη π.χ. χωριό / εξοχή / περιοχή καλλιέργειας

26. Ποια είναι η υψηλότερη βαθμίδα εκπαίδευσης που έχετε ολοκληρώσει; Εάν είστε ήδη εγγεγραμμένοι, λαμβάνεται ως ο υψηλότερος βαθμός:

- ☐ Απόφοιτος δημοτικού
- ☐ Απόφοιτος γυμνασίου
- ☐ Απόφοιτος λυκείου
- ☐ Πτυχίο Πανεπιστημίου Α.Ε.Ι/ Τ.Ε.Ι
- ☐ Πτυχίο Ι.Ε.Κ/Δ.Ι.Ε.Κ
- ☐ Μεταπτυχιακό
- ☐ Διδακτορικό

27. Ποια είναι η δεδομένη επαγγελματική σας κατάσταση;

- ☐ Εργαζόμενος
- ☐ Άνεργος
- ☐ Συνταξιούχος
- ☐ Φοιτητής/Μαθητής

28. Πώς θα χαρακτηρίζατε την οικονομική σας κατάσταση (εισόδημα);

- ☐ Εξαιρετικά ικανοποιητική
- ☐ Ικανοποιητική
- ☐ Ούτε ικανοποιητική ούτε δύσκολη
- ☐ Κάπως δύσκολη
- ☐ Εξαιρετικά δύσκολη

Με την υποβολή του ερωτηματολογίου συναινείτε στον γενικό Κανονισμό που αφορά την ασφάλεια των προσωπικών σας δεδομένων - GDPR - Γενικός κανονισμός για την προστασία δεδομένων (GDPR EU 2016/679). Τα στοιχεία και οι απαντήσεις σας θα καταγραφούν μόνο για εύλογο χρονικό διάστημα που αφορά την ακαδημαϊκή έρευνα και τις στατικές αναλύσεις της διπλωματικής μελέτης και έπειτα θα διαγραφούν.https://eur-lex.europa.eu/legal-content/EL/TXT/?uri=CELEX%3A02016R0679-20160504&qid=1532348683434

Συμφωνείτε να γίνει χρήση του προσωπικού σας email σας προς αποστολή σας για νέα πιθανά ερευνητικά ερωτηματολόγια ή συνεντεύξεις που αφορούν στην ίδια διπλωματική εργασία;

- ☐ Ναι
- ☐ Όχι

APPENDIX 3; Complementary tables 16a, 17a to Tables 16 & 17

Table 16a

Food Group	Mode Score (Score Range)	p-value	A [n(%)]	B [n(%)]	C [n(%)]	D [n(%)]	E [n(%)]
Milk	13.0 (11.0 , 15.0)	**0,000**	-	-	-	7 (6.7)	97 (93.3)
Milk Imitations	8.0 (6.0 , 12.0)		-	-	35 (23.2)	54 (35.8)	62 (41.1)
Flavored Milk	18.0 (17.0 , 19.0)	**0,000**	-	-			15 (100)
Flavored Milk Imitations	12.0 (12.0 , 14.0)		-	-		6 (12.2)	43 (87.8)
Yogurt	-1 (-2 , 1)	0,001	72 (56.3)	42 (32.8)	14 (10.9)	-	-
Plant-based yogurt	0 (-1 , 3)		13 (33.3)	16 (41.0)	10 (25.6)	-	-
Cheese	16.0 (13.0 , 17.0)	**0,000**	2 (1.3)	3 (1.9)	14 (8.9)	125 (79.1)	14 (8.9)
Plant-based Cheese	21.0 (17.0 , 22.0)		3 (4.2)	1 (1.4)	9 (12.7)	7 (9.9)	51 (71.8)
Milk Cream	23.0 (22.0 , 23.0)	0,026	-	2 (6.7)	1 (3.3)	6 (20.0)	21 (70.0)
Milk Cream Immitation	19.0 (12.5 , 23.0)		-	6 (35.3)	2 (11.8)	2 (11.8)	5 (41.2)
Ice cream	16.0 (12.0 , 19.0)	0,075	1 (2.6)	1 (2.6)	2 (5.3)	23 (60.5)	11 (28.9)
Vegan Ice Cream	14.5 (12.0 , 16.0)		-	-	4 (16.7)	20 (83.3)	-

Table 17b

Food Group	Mode Score (Score Range)	p-value	A [n(%)]	B [n(%)]	C [n(%)]	D [n(%)]	E [n(%)]
Cold Cuts	13.0 (11.0 , 19.3)	0,026	-	-	8 (14.8)	32 (59.3)	14 (25.9)
Cold Cuts Imitations	10.5 (6.5 , 15.3)		-	-	7(50)	6 (42.9)	1 (7.1)
Sausage	17.0 (16.0 , 21.0)	**0,000**	-	-	-	12 (57.1)	9 (42.9)
Sausage Imitations	11.0 (3.5 , 13.0)		1 (5.9)	1 (5.9)	5 (29.4)	9 (52.9)	1 (5.9)
Red meat	12.0 (7.5 , 12.5)	0,042	1 (5.9)	2 (11.8)	1 (5.9)	12 (70.6)	1 (5.9)
Red meat imitation	4.0 (1.0 , 12.0)		9 (18)	10 (20)	11 (22)	17 (34)	3 (6)
Poultry	16.2 (-1 , 19.9)	0,089	2 (10.5)	7 (36.8)	1 (5.3)	8 (42.1)	1 (5.3)
Poultry imitation	8.2 (-6 , 23.2)		3 (18.8)	4 (25.0)	5 (31.3)	3 (18.8)	1 (6.3)

APPENDIX 4; Table of multiple comparisons of meat imitation products

Multiple Comparisons							
Bonferroni							
Dependent V	(I) Ingr.Base	(J) Ingr.Base	Mean Differe	Std. Error	Sig.	99% Confidence Interval	
						Lower Bounc	Upper Bound
Energy_kcal	Soy/tofu	Wheat/seita	-27,5024	21,1685	0,591	-91,281	36,276
		Other pulses	-2,6432	20,8664	1	-65,512	60,225
	Wheat/seita	Soy/tofu	27,5024	21,1685	0,591	-36,276	91,281
		Other pulses	24,8592	17,818	0,499	-28,825	78,543
	Other pulses	Soy/tofu	2,6432	20,8664	1	-60,225	65,512
		Wheat/seita	-24,8592	17,818	0,499	-78,543	28,825
Protein_g	Soy/tofu	Wheat/seita	-9,7857	6,0954	0,005	-28,178	8,607
		Other pulses	-4,0006	6,1264	1	-22,487	14,485
	Wheat/seita	Soy/tofu	9,7857	6,0954	0,005	-8,607	28,178
		Other pulses	5,7851	5,1882	0,005	-9,87	21,44
	Other pulses	Soy/tofu	4,0006	6,1264	1	-14,485	22,487
		Wheat/seita	-5,7851	5,1882	0,005	-21,44	9,87
Total_Fat_g	Soy/tofu	Wheat/seita	0,4939	4,0831	1	-11,826	12,814
		Other pulses	-5,9143	4,1038	0,459	-18,297	6,469
	Wheat/seita	Soy/tofu	-0,4939	4,0831	1	-12,814	11,826
		Other pulses	-6,4082	3,4754	0,206	-16,895	4,079
	Other pulses	Soy/tofu	5,9143	4,1038	0,459	-6,469	18,297
		Wheat/seita	6,4082	3,4754	0,206	-4,079	16,895
Saturated_Fa	Soy/tofu	Wheat/seita	0,953	3,015	1	-8,154	10,06
		Other pulses	-4,0498	2,9824	0,534	-13,058	4,958
	Wheat/seita	Soy/tofu	-0,953	3,015	1	-10,06	8,154
		Other pulses	-5,0028	2,5816	0,168	-12,8	2,795
	Other pulses	Soy/tofu	4,0498	2,9824	0,534	-4,958	13,058
		Wheat/seita	5,0028	2,5816	0,168	-2,795	12,8
Carbo_g	Soy/tofu	Wheat/seita	2,7723	1,6141	0,268	-2,1	7,644
		Other pulses	2,338	1,6141	0,453	-2,534	7,21
	Wheat/seita	Soy/tofu	-2,7723	1,6141	0,268	-7,644	2,1
		Other pulses	-0,4343	1,3765	1	-4,589	3,721
	Other pulses	Soy/tofu	-2,338	1,6141	0,453	-7,21	2,534
		Wheat/seita	0,4343	1,3765	1	-3,721	4,589
Sugar_g	Soy/tofu	Wheat/seita	0,0462	0,3749	1	-1,086	1,178
		Other pulses	0,0115	0,3729	1	-1,114	1,137
	Wheat/seita	Soy/tofu	-0,0462	0,3749	1	-1,178	1,086
		Other pulses	-0,0347	0,3203	1	-1,002	0,932
	Other pulses	Soy/tofu	-0,0115	0,3729	1	-1,137	1,114
		Wheat/seita	0,0347	0,3203	1	-0,932	1,002
Fiber_g	Soy/tofu	Wheat/seita	1,725	3,3567	1	-8,828	12,278
		Other pulses	-0,9131	2,4294	1	-8,551	6,725
	Wheat/seita	Soy/tofu	-1,725	3,3567	1	-12,278	8,828
		Other pulses	-2,6381	3,1077	1	-12,408	7,132
	Other pulses	Soy/tofu	0,9131	2,4294	1	-6,725	8,551
		Wheat/seita	2,6381	3,1077	1	-7,132	12,408
Salt_g	Soy/tofu	Wheat/seita	-0,369432	0,407685	1	-1,60124	0,86237
		Other pulses	-0,626429	0,409967	0,391	-1,86513	0,61227
	Wheat/seita	Soy/tofu	0,369432	0,407685	1	-0,86237	1,60124
		Other pulses	-0,256996	0,353528	1	-1,32517	0,81117
	Other pulses	Soy/tofu	0,626429	0,409967	0,391	-0,61227	1,86513
		Wheat/seita	0,256996	0,353528	1	-0,81117	1,32517