Krakow Review of Economics and Management
Zeszyty Naukowe Uniwersytet Ekonomiczny w Krakowie
3 (1009)
2025

KREM, 2025, 3(1009): 5–22
ISSN 1898-6447
e-ISSN 2545-3238
https://doi.org/10.15678/krem.18646

Challenges in the Plant-based Dairy Alternatives Market: A Case Study of Ripened Rennet Cheese Alternatives in the Context of Sustainable Development Policy Principles

Urszula Samotyja[1], **Kamila Kuźnik**[2]

[1] Poznań University of Economics and Business, Institute of Quality Science, Department of Food Quality and Safety, Niepodległości 10, 61-875 Poznań, Poland, e-mail: urszula.samotyja@ue.poznan.pl, ORCID: https://orcid.org/0000-0001-7388-0852

[2] Poznań University of Economics and Business (graduate), Niepodległości 10, 61-875 Poznań, Poland, ORCID: https://orcid.org/0009-0003-6857-1010

Suggested citation: Samotyja, U., & Kuźnik, K. (2025). Challenges in the Plant-based Dairy Alternatives Market: A Case Study of Ripened Rennet Cheese Alternatives in the Context of Sustainable Development Policy Principles. *Krakow Review of Economics and Management / Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie*, 3(1009), 5–22. https://doi.org/10.15678/krem.18646

ABSTRACT

Objective: To determine whether the production and consumption of plant-based dairy alternatives (PBDAs) aligns with sustainable development policy and to identify challenges on the path to achieving Sustainable Development Goals (SDGs).

Research Design & Methods: A review and critical analysis of the literature, official documents, reports, food labels, and legal regulations. Synthesis and logical reasoning methods are also employed.

Findings: Contradictions have been identified between the principles of sustainable development policy and the directions the current PBDAs market is taking *vis-à-vis* ripened rennet cheese substitutes. The low nutritional value of PBDAs, inefficient resource utilisation in the production

of non-nutritive foods, and challenges arising from the need to sustainably feed a growing population may all hinder the achievement of SDGs.
Implications/Recommendations: The challenges identified can be a subject of research into consumer acceptance of plant-based alternatives. Further development is required to increase the adequacy and economic availability of PBDAs.
Contribution: The article sheds new light on the development of the PBDAs market in the context of the convergence of this trend with the principles of sustainable development policy.

Article type: original article.

Keywords: sustainable development, SDGs, sustainable consumption, sustainable production, plant-based food, sustainable food system.

JEL Classification: Q01, Q56, L15, L66, O13, P46.

1. Introduction

In developed countries over the last few years, a shift in the consumption model has been observed. This transformation has involved a complete or partial abandonment of meat and animal-derived products in favour of plant-based food, which includes plant-based meat alternatives, dairy alternatives, and other plant-based foods. In 2021, following the rapid expansion of the global plant-based food market, an optimistic forecast was published: Further growth was projected to reach 77.8 billion US dollars by 2025, and the market would more than double in value by 2030 (Plant Based News, 2021).

Contrary to these initial forecasts, the upward trend today has moderated, while the projected growth rates have been tempered, especially in the plant-based meat alternatives market (Terazono, 2022). Retail sales of plant-based foods in 13 European countries – Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Poland, Portugal, Romania, Spain, Sweden, and the United Kingdom – increased by 15% from 2020 to 2021. In 2022, they rose another 6% compared to 2021, reaching a total value of 5.8 billion euros. The most developed plant-based product category is beverages, with sales reaching 2.2 billion euros in Europe in 2022. Plant-based meat alternatives, the second-largest category in Europe, had sales of 2 billion euros (NielsenIQ, 2022).

Plant-based dairy and meat alternatives have become a global consumer trend among higher-income populations. They appeal to those with food allergies and intolerances, those seeking to avoid diet-related diseases, and those with environmental, ethical, and religion-based concerns (Giacalone, Clausen & Jaeger, 2022). Others are curious or seek to diversify their diet (Ruby *et al*., 2013). According to recent estimates, food production is responsible for approximately 30% of anthropogenic greenhouse gas emissions, 70% of freshwater usage, and the occupation of

37% of ice-free land surfaces. This makes it a significant driver of environmental change globally (Willet *et al*., 2019). Given the role the food system plays in biodiversity loss, climate change, and resource depletion, there is an urgent need for it to be transformed – on a global scale (Hoehnel, Zannini & Arendt, 2022). An analysis of the current food system reveals that food consumption patterns in the European Union are unsustainable, in terms of both the environment and human health (European Commission, 2020). In light of these facts, it is imperative that how raw materials are sourced and how food is produced, processed, consumed, and disposed of be shifted (Henchion *et al*., 2017).

The Farm to Fork Strategy, a pillar of the European Green Deal, takes a comprehensive approach to addressing the challenges of sustainable food systems. It recognises the interconnectedness between the well-being of people, societies, and the planet. It also plays a crucial role in the European Commission's efforts to achieve the United Nations' Sustainable Development Goals (SDGs) (European Commission, 2020). The growing consumer interest in using alternative protein sources to replace protein-rich foods derived from livestock aligns with the increasing demand for more sustainable food systems (Pingali *et al*., 2023). Sustainable development could therefore be pursued by growing the market for plant-based dairy alternatives (PBDAs). The expansion of the market for dairy and meat alternatives, both in terms of value and variety, has led to the growth of plant-based foods, though with unclear implications for nutrition, health, and the environment (Clegg *et al*., 2021; Wickramasinghe *et al*., 2021; Costa *et al*., 2023; Pingali *et al*., 2023). Given these developments, it is important to question whether the growing market for plant--based alternatives to conventional products aligns with global needs and challenges.

The aim of this paper is twofold: First, to consider whether the production and consumption of PBDAs align with principles of sustainable development policy and, second, to identify challenges on the path to achieving SDGs. To achieve these objectives, a review and critical analysis of the subject literature was carried out, including an examination of secondary sources such as official documents, reports, and legal regulations. Additionally, synthesis and logical reasoning methods were also employed. The analysis focuses on a specific case study involving ripened rennet cheese alternatives available in the Polish market. Their composition and nutritional value are examined and compared with Gouda cheese. The composition and nutritional value analyses were conducted based on data from the literature, as well as information obtained from product labels and product sheets. It is worth noting that replicating the functionality of plant-based ingredients to create other plant-based products, such as alternatives to ripened rennet cheese, is a complex process that requires more intricate processing to mimic the composition, unique nutrient profile, structure, shelf life, sensory quality and physicochemical properties (Grasso *et al*., 2021; Craig, Mangels & Brothers, 2022). The article sheds new light

on the development of the PBDAs market in the context of the convergence of this trend with the principles of sustainable development policy. The study contributes to the understanding of the complex relationships and threats related to food consumption in the context of achieving SDGs. In Poland, this line of research was initiated by Wiśniewska (2022).

2. Plant-based Dairy Alternatives

Plant-based dairy alternatives are now being offered by an increasing number of food business operators (FBOs). Some of these operators focus exclusively on producing plant-based foods, while others originate from the dairy industry and have expanded their product portfolios to include plant-based offerings. There is also a smaller group of companies that previously produced dairy products but have now shifted their focus to plant-based food production (Boba & Sosin, 2023).

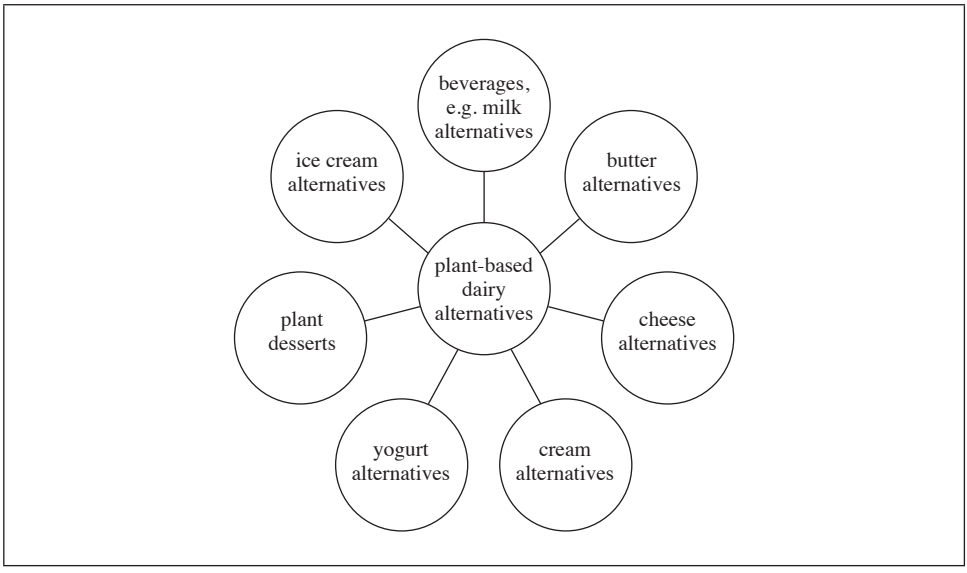

Fig. 1. Assortment of Plant-based Dairy Alternatives
Source: the author, based on World Food Poland (2023).

The market offers a wide variety of PBDAs (Fig. 1). Among them, the most popular category, an extensive one, is plant-based beverages. These beverages include options like soy, oat, coconut, almond, rice, hemp, or combinations thereof, such as oat-almond or coconut-rice. Another category, plant-based yogurt alternatives, is made from similar plant-based ingredients as the beverages, including oats, soy, coconut and cashews. Cheese alternatives are typically based on cashews and

coconut fat, while butter substitutes are primarily derived from coconut, rapeseed, or cashew fat. Plant-based cream alternatives are products made from ingredients like water, coconut beverage, or oat, soy, lentil, or almond flour. Ice cream alternatives are produced using plant oils, such as sunflower or coconut, in combination with plant-based beverages. As of February 2023, there were approximately 400 of these products available on the Polish market, and new ones continue to emerge regularly (World Food Poland, 2023).

3. Ripened Rennet Cheeses and Their Plant-based Alternatives

More than 1,000 cheese varieties can be created through a range of production and aging techniques (Grossmann & McClements, 2021). Ripened rennet cheeses are crafted through the careful processing of milk curd induced by rennet, leading to a product with a distinct aroma, flavour, and characteristic plasticity. Rennet cheese is widely acknowledged as a nutritious food, renowned for its rich content of essential nutrients, including fats, proteins, significant quantities of calcium and phosphorus, with an ideal ratio for absorbability, vitamin A, beta-carotene, and zinc (Kunachowicz *et al*., 2018).

For many years, cheese alternatives made with plant-derived fats were seen as inexpensive and less nutritious imitations of cheeses, i.e. food produced from animal milk. In some cases, they were even considered food adulteration. Nevertheless, in recent years the production of plant-based cheese alternatives has taken off, a shift driven by changing consumption habits and growing consumer interest in foods made from plant-based ingredients (Aschemann-Witzel *et al*., 2021). In 2022, the revenue generated from the sales of plant-based cheese alternatives in Poland reached almost 77 million złotys, 17% higher than in 2021 (The Good Food Institute, 2023).

Grossman and McClements (2021, p. 209) defined plant-based cheese[1] as "an edible material prepared from plant ingredients that is designed to have a similar appearance, texture, and flavour as animal-based cheeses." The fundamental principle guiding the production of plant-based cheese alternatives is to replicate the physicochemical and sensory characteristics of specific cheese by employing various plant-based ingredients and structuring techniques. This poses a significant challenge because plant-derived ingredients have different properties than animal milk, the primary ingredient in cheese production (Grossman & McClements, 2021). It is evident that the nutritional value of rennet cheese alternatives is contingent on the ingredients used to produce it, as is the case with any food product.

[1] In the EU the term "cheese" shall be reserved exclusively for milk products (Regulation (EU) No 1308/2013).

In the Polish market, several plant-based rennet cheese alternatives are available, offered by various suppliers in forms such as blocks, slices, and grated options. Within the product range of the same manufacturer, these alternatives generally share a similar composition, with variations typically attributed to the presence of specific flavour additives or different forms (blocks, slices or grated). Following the preliminary analysis of the compositions of 30 alternatives of ripened rennet cheese, seven of the most distinct products were selected for further examination. The results are described in the subsequent section.

Table 1. Ingredients Used in the Production of Ripened Rennet Cheese Gouda and Its Plant-based Alternatives

Food Product	Ingredients
Ripened rennet cheese	
Gouda	pasteurised milk, bacterial cultures, salt, stabiliser: calcium chloride, microbial rennet
Plant-based alternatives to ripened rennet cheese	
1	water, vegetable fat (coconut oil 24%), modified potato starch, tapioca starch, salt, olive extract, natural flavours, colour: beta-carotene, vitamin B12
2	water, coconut oil (23%), modified starch, starch, sea salt, flavours, olive extract, colour: beta-carotene, vitamin B12
3	water, coconut oil 23%, modified starch, salt, Gouda flavour (glucose, salt, flavour, yeast extract), calcium, stabiliser: calcium chloride, preservative: potassium sorbate, vitamins: niacin, pantothenic acid, B6, B12, folic acid, biotin, colours: carotenes, acidity regulator: citric acid
4	water, vegetable oil (coconut oil) 23%, modified starch, salt, Gouda flavour, colour: carotenes
5	water, coconut oil, starch, stabilisers (gum arabic, locust bean gum, agar), pea protein (2.3%), sea salt, seasonings, natural aroma, antioxidant: citric acid
6	almond filling 52% (water, almonds 2%), coconut oil, modified starch, starch, flavour, salt, carrot and apple concentrate, antioxidant: sodium ascorbate
7	water, coconut fat 21%, starch, maltodextrin, salt, modified starch, stabiliser: xanthan gum, acidity regulators: lactic acid, calcium lactate, colour: carotenes, flavouring mixture (glucose, salt, flavour, yeast extract)

Source: the author, based on label and product sheet.

As indicated in Table 1, the primary formulation ingredients for rennet cheese alternative-products include water, vegetable fat (coconut oil), and starch. Among the products showcased, one was made primarily from almond paste (53%), with water constituting the primary ingredient and almonds accounting for only 2%. The coconut oil content in the seven plant-based cheese alternatives typically amounts to about 23%, which contrasts with the composition of milk fat, where no

fats beyond animal fat are present. Few cheese alternatives are fortified with the important nutrients present in milk products – vitamin B12 and calcium, which are critical for vegans.

All cheese alternatives are coloured to achieve a yellow hue (natural colour of rennet cheese resulting from beta-carotene content in milk), often using ingredients like beta-carotene or carrot concentrate, and they are also flavoured. On a related note, the formulations of these alternatives do not align with the consumer trend of "short and clean labels" (Maruyama, Streletskaya & Lim, 2021), as the ingredient lists tend to be relatively complex and may include food additives according to Commission Regulation (EU) No 1129/2011. In conventional rennet cheese, calcium chloride is commonly used, whereas in their plant-based alternatives, more food additives are employed. Such additives include potassium sorbate, citric acid, carotenes, gum arabic, locust bean gum, sodium ascorbate, lactic acid, and calcium lactate.

Table 2 presents the nutritional value of ripened rennet cheese Gouda and selected cheese alternatives.

Table 2. Nutritional Value of Ripened Rennet Cheese Gouda and Its Plant-based Alternatives

Energy Value and Nutrient Content in 100 g of Product								
Specification	Gouda cheese	1	2	3	4	5	6	7
Energy (kJ/kcal)	1323/ 318	1296/ 312	1190/ 285	1210/ 292	1225/ 295	1130/ 273	1123/ 270	1126/ 271
Fat (g)	23	24	23	23	23	23	19	21
of which saturates (g)	14	21	21	20	21	20	17	19
Carbohydrate (g)	0.1	24	20	20	22	14	24	20
of which sugars (g)	0.1	0	0	0.2	0	0.1	< 0.5	< 0.5
Fibre (g)	0	.	.	.	.	1.5	.	.
Protein (g)	27	0	0	0.4	0	1.4	0.7	< 0.5
Salt (g)	2.3	2.1	2.3	2.3	2.3	0.9	2.7	2.3
Calcium (mg)	807	.	.	126	.	.	.	.

Source: the author, based on information from the label, product sheet and Kunachowicz *et al*. (2018).

Caloric content, derived from the nutritional composition, is slightly lower for plant-based alternatives than for cheese. The fat content ranges from 19 to 23 g/100 g, compared to 24 g/100 g in Gouda. Both cheese and its plant-based alternatives contain predominantly saturated fatty acids, but the dairy product has a lower quantity and proportion of saturated fatty acids. Fatty acids derived from milk have a different fatty acid profile than those derived from coconut oil. They also contain accompa-

nying substances, such as cholesterol and conjugated diene isomers of linoleic acid (CLA) (Mojska *et al*., 2020). A significant difference between conventional cheeses and their alternatives is the protein content. It is present in only some alternatives and often in very low or negligible amounts. The recommendation formulated for the Polish adults is that protein should account for 10–20% of energy intake (Charzewska *et al*., 2020). According to Regulation (EC) No 1924/2006 of the European Parliament and of the Council, a product can claim to be a "source of protein" only when at least 12% of the energy value of the food is provided by protein. In rennet cheese, protein covers about 34% of its energy value. For product no. 5 – the best source of protein among the seven alternatives analysed – energy from protein contributes only 2% of the total energy content. Product no. 5 also contained 1.5 g of fibre/100 g. A claim that a food is a "source of fibre," and any claim likely to have the same meaning for the consumer, may only be made where the product contains at least 3 g of fibre per 100 g or at least 1.5 g of fibre per 100 kcal. This condition is not met; nevertheless, cheeses are not a source of fibre, so the absence of such a declaration is not a drawback in this case.

While conventional dairy products typically have low or no sugar content, plant-based rennet cheese alternatives do contain notable amounts of carbohydrates. These carbohydrates result from starch, helping achieve the desired texture and consistency of the product. The results of studies conducted in various countries, including the United Kingdom, the USA, and Spain, from 2019 to 2021, indicated that cheese alternatives were characterised by a low nutritional value, particularly low protein content, and high carbohydrate and saturated fatty acid content (Szymańska, 2022). Unlike plant-based meat alternatives, which have comparable amounts of protein to conventional meat, the protein content of plant-based dairy varies widely, with only legume-based beverages containing protein concentrations comparable to milk (Boeck *et al*., 2021). Cheese alternative no. 3 was fortified with calcium, but at a level six times lower than that in milk.

4. Development of the Market for Rennet Cheese Alternatives in the Context of Sustainable Development Policy

Plant-based dairy alternatives have the potential to provide additional sources of nutrients, reduce the overall environmental impact, improve animal welfare, and promote positive health effects through phytonutrients. As consumer awareness of such alternatives rises and dietary patterns change, PBDAs may be aligned with the following SDGs: 2, 3, 12, and 13. Including plant-based food in a diversified balanced diet would improve the health status of the population and offer environmental and economic advantages. However, attaining these goals may be hindered by a range of challenges, which, if not addressed appropriately, could become threats (Table 3).

Table 3. Targets and Challenges in Achieving SDGs in Connection with Market Development of Ripened Rennet Cheese Alternatives

Targets	SDG	Challenges
– 2.1. "(…) end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round" – 2.2. "(…) end all forms of malnutrition, (…) address the nutritional needs of adolescent girls, pregnant and lactating women and older persons"	SDG 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture	– does not meet the criteria of "source of protein" as per regulations – risk of calcium deficiencies in vulnerable population groups, such as pregnant women, nursing mothers, and older persons – challenges posed by the need to feed a growing population – high price compared to milk products
– 3.4. "(…) reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being"	SDG 3 Ensure healthy lives and promote well-being for all at all ages	– reduced nutritional value compared to conventional products – an increased risk of diet-related diseases due to high saturated fatty acids and carbohydrates from non-nutritive sources
– 12.2. "(…) achieve the sustainable management and efficient use of natural resources" – 12.3. "(…) halve per capita global food waste at the retail and consumer levels (…)" – 12.8. "(…) ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature" – 12A. "Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production"	SDG 12 Ensure sustainable consumption and production patterns	– inefficient use of resources in the production of non-nutritive foods – challenges related to labelling – misalignment with the "short and clean label" trend – advanced technology that does not support sustainable consumption patterns
– 13.3. "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction (…)"	SDG 13 Take urgent action to combat climate change and its impacts	– environmental burden in the production of non-nutritive foods

Source: the author, based on United Nations (2015).

The burden of malnutrition includes both undernutrition (stunting and wasting) and overnutrition (overweight and obesity) and continues to be a major problem globally, especially in developing countries (Tabe-Ojong *et al*., 2024). A shift from consuming dairy products to plant-based alternatives should not result in reduced nutritional value – alternative products should contain at least similar nutritional value. If they do not, nutrient deficiency and nutritional inadequacy – consuming nutrients in amounts below the estimated average requirement – would only rise (Kiani *et al*., 2022).

As Table 2 showed, ripened rennet cheese alternatives are not a valuable source of nutrients, especially protein and calcium. Proteins are essential structural and functional elements in every cell of the human body. They are crucial for the growth and development of the human body and regulate gene expression. As biocatalysts, proteins are involved in many enzymatic systems and help regulate various metabolic processes. High-quality sources of protein include eggs, dairy products, meat, fish, and poultry. Increased demand for protein occurs in pregnant and breastfeeding women, young individuals, elderly, and in various medical conditions (Charzewska *et al*., 2020).

Calcium is a fundamental building block of bones and teeth. It also plays a role in conducting nerve impulses, muscle contraction, activation of certain enzymes, hormonal regulation, and blood clotting. Calcium is essential for the proper functioning of the heart, the vascular system, and the regulation of blood pressure. Including an adequate amount of calcium in the diet is crucial for preventing conditions such as obesity, type 2 diabetes, and certain types of cancer (Wojtasik *et al*., 2020).

Deficiencies of essential nutrients are associated with an increased risk of a wide range of diseases. The nutritional inadequacy of ripened rennet cheese alternatives is not currently satisfactory and calls for further exploration of alternative sources of nutrients. Consumers should be aware that they need to obtain nutrients from other sources.

The challenge is to reformulate these PBDAs in a way they would be nutritious. Unfortunately, there has been no improvement in the nutrient profile of rennet cheese alternatives in the past year, especially when considering protein content (Szymańska, 2022). Similar observations were made regarding other PBDAs. In a study examining the nutritional profile of ultra-processed plant-based burgers, Vellinga *et al*. (2024) found that the profile of amino acids indicated a low nutritional value of protein. This issue may pose a threat to the implementation of targets 2.1 and 2.2, which reference the need to reduce malnutrition, ensuring access to sufficient safe, nutritious food and to address the special nutritional needs of vulnerable groups including the elderly, adolescent girls and pregnant women.

Point 2.1 of the SDG addressed the issue of accessibility. Economic availability implies that all social groups, including the poorest, can afford to purchase food. Although this topic is not directly addressed in this paper, other analyses have shown that plant-based products tend to cost more than conventional ones made with animal proteins (Batista *et al*., 2023). Plant-based rennet cheese alternatives are no exception. Additionally, unlike their substitutes, conventional cheeses are often available in bulk, allowing customers to purchase them by weight, which can be a more cost-effective and environmentally friendly option. The higher price of PBDAs can affect their economic availability. For some products, a higher price is generally seen as a drawback, particularly for low-income consumers, and may limit the growth of the plant-based alternatives market (Batista *et al*., 2023).

In the EU, average energy intake, consumption of red meat, sugars, salt, and fats continue to exceed recommended values, while there is insufficient consumption of whole-grain cereals, fruits, vegetables, legumes, and nuts (Willet *et al*., 2019). In rennet cheese alternatives, carbohydrates are sourced from thickeners rather than whole-grain, nutritious ingredients. A carbohydrate-heavy diet may lead to being overweight or obese (Przygoda, Jarosz & Sajór, 2020). Dietary fat is an essential nutrient, but it is recommended that daily energy intake from fats not exceed 30%. The fatty acid profile is of particular importance. Unfortunately, coconut fat predominantly consists of saturated fatty acids, making it an unhealthy choice for some (Mojska *et al*., 2020).

There is ongoing debate about how to label PBDAs because they do not fully substitute for traditional dairy products in terms of nutritional value. Pérez--Rodríguez *et al*. (2023) maintained that these products should not be considered an alternative to milk, but as different products – each with its own nutritional and functional characteristics. In light of the presented data on nutritional value of plant-based ripened rennet cheese alternatives, Nicolás Saraco and Blaxland (2020) recommend the term "imitation," rather than the more common "alternatives" or "substitutes."

SDG 12.8 refers to the importance of informing people about the impact of their lifestyles on sustainable development. In this context, the data presented in Table 2 indicate the need to provide consumers with reliable information on the consequences of regular and exclusive consumption of PBDAs regarding their composition and properties. Frequent consumption of alternatives instead of conventional products could potentially have a detrimental effect on nutrient intake, especially for less health-conscious consumers who do not prioritise a varied diet. Therefore, legal regulations regarding name and labelling of ripened rennet cheese alternatives are extremely important, as they help consumers make informed decisions.

Sustainable development policies are intended to empower consumers to make informed, healthy, and sustainable dietary choices. It is therefore crucial that food

labelling, food presentation and marketing communication not be misleading, be clear and understandable, and not raise doubts that could negatively impact human health due to uninformed choices (Kamińska & Dmowski, 2023). Furthermore, food production requires the use of resources such as land, water, labour, energy, and leads to the emission of greenhouse gases (Willet *et al*., 2019; Chen, Chaudhary & Mathys, 2020). Producing non-nutritive foods causes unjustified burden on the environment and may lead to unnecessary and inefficient resource utilisation. With forecasts indicating that the global population will reach 10 billion by 2050 (Searchinger *et al*., 2019; United Nations, 2022), prioritising resource management and efficient use to end hunger (SDG 2) should be essential. Given this, the availability of ripened rennet cheese alternatives on the market poses a challenge to achieving SDG 3, which focuses on ensuring healthy lives and promoting well--being, as well as SDG 12, which aims to promote sustainable consumption patterns. Moreover, unclear labels, misleading names, and the purchase of products based on trends without considering their composition, properties, or impact on resource management hinder the achievement of SDG 13, which focuses on combating climate change.

There is a need to raise awareness among both PBDAs producers, who can influence consumer choices, and consumers themselves. According to Schiano *et al*. (2020), consumers may be biased toward believing that PBDAs are more sustainable than their dairy counterparts. They stated that product labels are the most common source of sustainability information and emphasised that FBOs should assist consumers in making informed decisions by simplifying sustainability--related messaging and maintaining open, transparent communication on the subject. Additionally, Vellinga *et al*. (2024) highlighted the need for PBDAs manufacturers to make improvements to better support healthy dietary habits, including reducing energy, sodium, and total fat content, as well as improving the quality of proteins used in their formulations. Schiano *et al*. (2020) also showed a misalignment between consumer and industry definitions of sustainability, which, if addressed, could lead to the development of marketing messaging that resonates more effectively with consumers.

Another challenge concerns technological difficulties arising from the need to replicate the shelf life, sensory and textural properties of dairy ingredients. To achieve this, manufacturers use flavours and permitted additives, such as colours, acidity regulators, stabilisers, and thickeners. The current state of technological advancement does not allow for the replication of cheese's organoleptic properties using a short list of ingredients. An increasing number of consumers expect product compositions to be simple and free from additives, especially thickeners and stabilisers (Maruyama, Streletskaya & Lim, 2021). At present, rennet cheese substitutes do not meet consumer expectations. It is hoped that growing consumer

demand for these products will drive technological advancements, which can then be transferred to developing countries, supporting the achievement of target 12A. Producing a stable product that meets consumer expectations in terms of sensory quality, nutritional value and shelf life will help reduce the risk of food waste. By following these development pathways, PBDAs producers can contribute to the achievement of target 12.3, which focuses on reducing food waste at both the retail and consumer levels.

5. Managerial Implications

The study provides valuable insights into the role of the PBDAs market in sustainable development policy, specifically regarding ripened rennet cheese alternatives. It identifies challenges in achieving the SDGs and clearly underscores the need for further development of technology and formulations for rennet cheese alternatives to address global challenges.

Manufacturers of PBDAs can leverage these findings to better understand how to develop the market for alternatives to animal-origin products, thereby improving their marketing strategies, enhancing competitiveness, and positively impacting their public image and trust. The paper demonstrates the complexity of the relationships and connections at issue. For this reason, the impending transformation is likely to be time-consuming and costly, and to require substantial investment in research and development. The study also highlights the important task that FBOs face in helping consumers make sustainable choices.

This study serves as an entry point for policy intervention. The paper can assist food regulatory bodies in formulating improved policies and regulations regarding plant-based products as alternatives to dairy, which may support sustainable development goals.

6. Limitations and Directions for Future Research

The limitation of this study is that it focuses solely on ripened rennet cheese alternatives. However, it is essential to consider other products to enable consumers to make sustainable choices from a diverse range of nutritious options. Some aspects of food products, such as sensory quality and shelf life, were beyond the scope of this research, but they also deserve attention. Lastly, researching consumer acceptance of new, improved formulas is crucial for improving their dietary patterns and habits.

7. Conclusions

While this research offers valuable insights for FBOs and policymakers, there are limitations that suggest potential for future research. The market for PBDAs

is undergoing rapid expansion, driven in part by increased consumer awareness of the impact of nutrition on health, as well as the effects consumption has on the environment and climate. This translates into a growing demand for these products. Therefore, it can be expected that the concept of sustainable development could be implemented through the development of this market.

The analysis uncovered contradictions between the principles of sustainable development policy and the development of the market for PBDAs, specifically rennet-free cheese substitutes. There are challenges that may hinder or even threaten the achievement of some sustainable development goals. According to the principles of SDG, efforts should be made to increase the market share of plant-based products, which can help reduce the consumption of animal-based products. At the same time, dietary recommendations call for the consumption of highly processed foods, including plant-based dairy and meat alternatives, to be limited. Food producers currently face significant challenges in meeting the requirements of sustainable development policies. To fully replace dairy products with plant-based dairy substitutes, issues related to their nutritional value must be addressed, along with considerations for the aspects mentioned above during technological transition. In the short term, the use of a varied diet can help mitigate the negative effects of imperfections.

Authors' Contribution

The authors' individual contribution is as follows: Urszula Samotyja 70%, Kamila Kuźnik 30%.

Conflict of Interest

The authors declare no conflict of interest.

References

Aschemann-Witzel, J., Gantriis, R. F., Fraga, P., & Perez-Cueto, F. J. A. (2021). Plant-based Food and Protein Trend from a Business Perspective: Markets, Consumers, and the Challenges and Opportunities in the Future. *Critical Reviews in Food Science and Nutrition*, *61*(18), 3119–3128. https://doi.org/10.1080/10408398.2020.1793730

Batista, L. F., Rocha, F., dos Santos Dias, M. M., dos Santos Pires, A. C., & Vidigal, M. C. T. R. (2023). Comfort Plant-based Food: What Do Consumers Want? – a Focus Group Study with Different Consumers Group. *International Journal of Gastronomy and Food Science*, *34*, 100810. https://doi.org/10.1016/j.ijgfs.2023.100810

Boba, D., & Sosin, S. (2023). *Roślinne alternatywy nabiału. Przewodnik dla producentów*. RoślinnieJemy. Retrieved from: https://roslinniejemy.org/publikacje/poradnik-dla-producentow-alternatyw-nabialu (accessed: 15.08.2023).

Boeck, T., Sahin, A. W., Zannini, E., & Arendt, E. K. (2021). Nutritional Properties and Health Aspects of Pulses and Their Use in Plant-based Yogurt Alternatives. *Comprehensive*

Reviews in Food Science and Food Safety, *20*(4), 3858–3880. https://doi.org/10.1111/1541-4337.12778

Charzewska, J., Jarosz, M., Wajszczyk, B., & Chwojnowska, Z. (2020). Białka. In: M. Jarosz, E. Rychlik, K. Stoś, J. Charzewska (Eds), *Normy żywienia dla populacji Polski i ich zastosowanie* (pp. 48–67). Narodowy Instytut Zdrowia Publicznego – Państwowy Zakład Higieny.

Chen, C., Chaudhary, A., & Mathys, A. (2020). Nutritional and Environmental Losses Embedded in Global Food Waste. *Resources, Conservation and Recycling*, *160*, 104912. https://doi.org/10.1016/j.resconrec.2020.104912

Clegg, M. E., Tarrado Ribes, A., Reynolds, R., Kliem, K., & Stergiadis, S. (2021). A Comparative Assessment of the Nutritional Composition of Dairy and Plant-based Dairy Alternatives Available for Sale in the UK and the Implications for Consumers' Dietary Intakes. *Food Research International*, *148*, 110586. https://doi.org/10.1016/j.foodres.2021.110586

Commission Regulation (EU) No 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives. Official Journal of the European Union, L 295/1.

Costa, M. P., Saget, S., Zimmermann, B., Petig, E., Angenendt, E., Rees, R. M., Chadwick, D. R., Gibbons, J., Shrestha, S., Williams, M., & Styles, D. (2023). Environmental and Land Use Consequences of Replacing Milk and Beef with Plant-based Alternatives. *Journal of Cleaner Production*, *424*, 138826. https://doi.org/10.1016/j.jclepro.2023.138826

Craig, W. J., Mangels, A. R., & Brothers, C. J. (2022). Nutritional Profiles of Non-dairy Plant-based Cheese Alternatives. *Nutrients*, *14*(6), 1247. https://doi.org/10.3390/nu14061247

European Commission. (2020). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. COM(2020) 381 final. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0381 (accessed: 7.08.2023).

Giacalone, D., Clausen, M. P., & Jaeger, S. R. (2022). Understanding Barriers to Consumption of Plant-based Foods and Beverages: Insights from Sensory and Consumer Science. *Current Opinion in Food Science*, *48*, 100919. https://doi.org/10.1016/j.cofs.2022.100919

The Good Food Institute. (2023). *Sales Value of Plant-based Cheese in Poland between 2021 and 2022* (*in Million Zloty*). Statista.

Grasso, N., Roos, Y. H., Crowley, S. V., Arendt, E. K., & O'Mahony, J. A. (2021). Composition and Physicochemical Properties of Commercial Plant-based Block-style Products as Alternatives to Cheese. *Future Foods*, *4*, 100048. https://doi.org/10.1016/J.FUFO.2021.100048

Grossmann, L., & McClements, D. J. (2021). The Science of Plant-based Foods: Approaches to Create Nutritious and Sustainable Plant-based Cheese Analogs. *Trends in Food Science & Technology*, *118*(A), 207–229. https://doi.org/10.1016/j.tifs.2021.10.004

Henchion, M. M., Hayes, M., Mullen, A. M., Fenelon, M. A., & Tiwari, B. K. (2017). Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods*, *6*(7), 53. https://doi.org/10.3390/foods6070053

Hoehnel, A., Zannini, E., & Arendt, E. K. (2022). Targeted Formulation of Plant-based Protein-foods: Supporting the Food System's Transformation in the Context of Human Health, Environmental Sustainability and Consumer Trends. *Trends in Food Science & Technology*, *128*, 238–252. https://doi.org/10.1016/j.tifs.2022.08.007

Kamińska, A., & Dmowski, P. (2023). Nazewnictwo bezalkoholowych odpowiedników napojów alkoholowych stosowane na rynku polskim w świetle krajowych i unijnych regulacji prawnych. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie*, 3(1001), 105–121. https://doi.org/10.15678/ZNUEK.2023.1001.0306

Kiani, A. K., Dhuli, K., Donato, K., Aquilanti, B., Velluti, V., Matera, G., Iaconelli, A., Connelly, S. T., Bellinato, F., Gisondi, P., & Bertelli, M. (2022). Main Nutritional Deficiencies. *Journal of Preventive Medicine and Hygiene*, *63*(2S3), E93–E101. https://doi.org/10.15167/2421-4248/jpmh2022.63.2S3.2752

Kunachowicz, H., Przygoda, B., Nadolna, I., & Iwanow, K. (2018). *Tabele składu i wartości odżywczej żywności*. PZWL.

Maruyama, S., Streletskaya, N. A., & Lim, J. (2021). Clean Label: Why This Ingredient but Not That One? *Food Quality and Preference*, *87*, 104062. https://doi.org/10.1016/j.foodqual.2020.104062

Mojska, H., Jasińska-Melon, E., Ołtarzewski, M., & Szponar, L. (2020). Tłuszcze. In: M. Jarosz, E. Rychlik, K. Stoś, J. Charzewska (Eds), *Normy żywienia dla populacji Polski i ich zastosowanie* (pp. 68–97). Narodowy Instytut Zdrowia Publicznego – Państwowy Zakład Higieny.

Nicolás Saraco, M., & Blaxland, J. (2020). Dairy-free Imitation Cheese: Is Further Development Required? *British Food Journal*, *122*(12), 3727–3740. https://doi.org/10.1108/BFJ-11-2019-0825

NielsenIQ. (2022). *Europe Plant-based Food Retail Market Insight 2020–2022*. Retrieved from: https://gfieurope.org/wp-content/uploads/2023/04/2020-2022-Europe-retail-market-insights_updated-1.pdf (accessed: 2.08.2023).

Pérez-Rodríguez, M. L., Serrano-Carretero, A., García-Herrera, P., Cámara-Hurtado, M., & Sánchez-Mata, M. C. (2023). Plant-based Beverages as Milk Alternatives? Nutritional and Functional Approach through Food Labelling. *Food Research International*, *173*(1), 113244. https://doi.org/10.1016/j.foodres.2023.113244

Pingali, P. L., Boiteau, J. M., Choudhry, A., & Hall, A. (2023). Making Meat and Milk from Plants: A Review of Plant-based Food for Human and Planetary Health. *World Development*, *170*, 106316. https://doi.org/10.1016/j.worlddev.2023.106316

Plant Based News. (2021). *Value of the Plant-based Food Market Worldwide from 2020 to 2030* (*in Billion U.S. Dollars*). Statista.

Przygoda, B., Jarosz, M., & Sajór, I. (2020). Węglowodany. In: M. Jarosz, E. Rychlik, K. Stoś, J. Charzewska (Eds), *Normy żywienia dla populacji Polski i ich zastosowanie* (pp. 134– 147). Narodowy Instytut Zdrowia Publicznego – Państwowy Zakład Higieny.

Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on Nutrition and Health Claims Made on Foods. Official Journal of the European Union, L 404/9.

Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007. Official Journal of the European Union, L 347/671.

Ruby, M. B., Heine, S. J., Kamble, S., Cheng, T. K., & Waddar, M. (2013). Compassion and Contamination. Cultural Differences in Vegetarianism. *Appetite*, *71*, 340–348. https://doi.org/10.1016/j.appet.2013.09.004

Schiano, A. N., Harwood, W. S., Gerard, P. D., & Drake, M. A. (2020). Consumer Perception of the Sustainability of Dairy Products and Plant-based Dairy Alternatives. *Journal of Dairy Science*, *103*(12), 11228–11243. https://doi.org/10.3168/jds.2020-18406

Searchinger, T., Waite, R., Hanson, C., & Ranganathan, J. (2019). *World Resources Report. Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050*. World Resources Institute. Retrieved from: https://research.wri.org/wrr-food (accessed: 10.08.2023).

Szymańska, I. (2022). Roślinne alternatywy dla serów: stan i perspektywy. *Przemysł Spożywczy*, *76*(11), 25–29. https://doi.org/10.15199/65.2022.11.5

Tabe-Ojong, M. P., Jr., Nana, I., Zimmermann, A., & Jafari, Y. (2024). Trends and Evolution of Global Value Chains in Food and Agriculture: Implications for Food Security and Nutrition. *Food Policy*, *127*, 102679. https://doi.org/10.1016/j.foodpol.2024.102679

Terazono, E. (2022). Beyond Meat Takes a Beating as Plant-based Sector Reports Slowing Sales. *Financial Times*. Retrieved from: https://www.ft.com/content/9ccf053a-e710-462f-9a8e-1dd0db13a523 (accessed: 18.10.2023).

United Nations. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development*. Retrieved from: https://sdgs.un.org/2030agenda (accessed: 1.08.2023).

United Nations. (2022). *Revision of World Population Prospects*. Retrieved from: https://population.un.org/wpp (accessed: 1.08.2023).

Vellinga, R. E., Rippin, H. L., Gonzales, B. G., Temme, E. H. M., Farrand, C., Halloran, A., Clough, B., Wickramasinghe, K., Santos, M., Fontes, T., Pires, M. J., Nascimento, A. C., Santiago, S., Burt, H. E., Brown, M. K., Jenner, K. H., Alessandrini, R., Marczak, A. M., Flore, R., … Motta, C. (2024). Nutritional Composition of Ultra-processed Plant-based Foods in the out-of-Home Environment: A Multi-country Survey with Plant-based Burgers. *British Journal of Nutrition*, *131*(10), 1691–1698. https://doi.org/10.1017/S0007114524000023

Wickramasinghe, K., Breda, J. J., Berdzuli, N., Rippin, H. L., Farrand, C., & Halloran, A. (2021). The Shift to Plant-based Diets: Are We Missing the Point? *Global Food Security*, *29*, 100530. https://doi.org/10.1016/J.GFS.2021.100530

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., De Vries, W., Majele Sibanda, L., … Murray, C. J. L. (2019). Food

in the Anthropocene: The EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems. *The Lancet*, *393*(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

Wiśniewska, M. Z. (2022). Ewolucja trendów i zagrożeń w konsumpcji żywności w świetle celów zrównoważonego rozwoju. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie*, 1(995), 63–79. https://doi.org/10.15678/ZNUEK.2022.0995.0104

Wojtasik, A., Woźniak, A., Stoś, K., & Jarosz, M. (2020). Składniki mineralne. In: M. Jarosz, E. Rychlik, K. Stoś, J. Charzewska (Eds), *Normy żywienia dla populacji Polski i ich zastosowanie* (pp. 273–315). Narodowy Instytut Zdrowia Publicznego – Państwowy Zakład Higieny.

World Food Poland. (2023). *Roślinne zamienniki nabiału*. Retrieved from: https://www.worldfood.pl/roslinne-zamienniki-nabialu (accessed: 5.03.2023).