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PURPLE SWEET POTATO AS A NATURAL STABILIZER IN DAIRY PRODUCTS

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dairy products, flour, natural stabilizer, sweet potato

ABSTRACT
Consumer interest in high-quality food is growing, especially in functional products. Milk and dairy products are high-nutrient sources that are often enriched with additives to enhance their bioactivity. However, dairy products such as yogurt can be prone to defects, including syneresis. The main components of yogurt, including protein (*casein and whey*), carbohydrates (*lactose*), milk fat, calcium, and lactic acid, play a crucial role in the formation and stability of the gel structure. Processing factors, such as heat treatment, temperature, and duration of storage, also affect the physical stability of the product. Generally, additives are used to maintain quality and sensory characteristics, but overconsumption of food with synthetic additives can negatively affect health. Therefore, the use of natural ingredients needs to be developed. Purple sweet potato flour is a natural ingredient that can serve as a stabilizer due to its high starch content. Starch has been widely used as a thickener, stabilizer, and gel former. In addition to starch, purple sweet potato flour contains anthocyanins that can increase the added value of the final product. This article aims to examine the potential use of the purple sweet potato as a nutrient-rich natural stabilizer.

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ФИОЛЕТОВЫЙ БАТАТ В КАЧЕСТВЕ НАТУРАЛЬНОГО СТАБИЛИЗАТОРА В МОЛОЧНЫХ ПРОДУКТАХ

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АННОТАЦИЯ
Интерес потребителей к высококачественным продуктам питания, в особенности к функциональным, продолжает возрастать. Молоко и молочные продукты являются богатыми источниками питательных веществ, которые часто обогащают добавками для повышения их биологической активности. Однако молочные продукты, такие как йогурт, могут быть подвержены возникновению пороков, в том числе синерезису. Основные компоненты йогурта, включая белок (казеин и сывороточные белки), углеводы (лактозу), молочный жир, кальций, и молочную кислоту, играют важную роль в формировании стабильности гелевой структуры. Технологические факторы, такие как режимы тепловой обработки, температура и продолжительность хранения, также влияют на стабильность физических параметров продукта. Как правило, для сохранения показателей качества и органолептических свойств используются добавки, но чрезмерное употребление продуктов с синтетическими добавками может негативно повлиять на здоровье. В связи с этим, необходимым является расширение ассортимента натуральных ингредиентов. Мука из фиолетового батата является натуральным ингредиентом, который может использоваться в качестве стабилизатора благодаря высокому содержанию крахмала. Крахмал широко используется в качестве загустителя, стабилизатора и гелеобразователя. Помимо крахмала, мука из фиолетового батата содержит антоцианы, что позволит характеризовать готовый продукт с ее содержанием, как продукт с добавленной пользой. Цель данной статьи — изучить перспективы применения фиолетового батата в качестве натурального стабилизатора.

1. Introduction

The development of the food industry today isn't focused solely on the taste and appearance of the product. Additionally, it offers functional added value that can provide health benefits to consumers. Consumer interest in high-quality food, especially in functional products, is increasing. Promotions on food quality and healthy lifestyles attract consumers' attention [1]. In general, functional foods can be produced from either natural or processed ingredients. Regular consumption of functional foods can provide health benefits [2,3].

The consumption of products with bioactive components is associated with a reduced risk of diseases, such as tumors, obesity, and metabolic syndrome [1]. Bioactive compounds, including carotenoids, anthocyanins, and phenolic compounds, can be found in sweet potato [3,4]. Purple sweet potato (*Ipomoea batatas*) is a type of tuber that can contribute to health due to its antioxidant, anti-obesity, hepatoprotective, antimicrobial, and other properties. The sweet potato can provide food products with color and flavor, while also increasing their nutritional value [5]. In 2018, purple sweet potato production reached 2 million tons. Sweet potato prices are relatively higher, especially when processed into a product. Purple sweet potato has good potential for wider use in the food industry [6].

Milk and dairy products are highly nutritious, providing protein and energy [7]. Nutritionists consider dairy products to be beneficial for human health. This is due to their high nutritional value and digestibility [8]. The composition of dairy products such as yogurt and ice cream can be modified and enriched with bioactive compounds [9]. Natural ingredients such as fruits and vegetables are often added. These additives can affect the quality of the final product (e. g., sensory properties such as taste, appearance, and aroma) [10,11,12]. The development of new food products is essential to meet consumer needs [13].

Yuliana et al. [14] stated that dairy products such as yogurt with fruit ingredients, for example, banana, are often prone to physical changes in the form of syneresis. Syneresis in products can occur due to a decrease in the ability to bind water during storage and transportation. The formation of sediment in beverages is a significant issue both in terms of quality and cost, which can negatively impact consumer acceptance. The chemical composition of the ingredients influences turbidity and sedimentation.

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Therefore, preventive measures should be focused on the chemical characteristics of each component [15]. The addition of stabilizers can prevent the instability of food products. Stabilizers are added to improve texture, mouthfeel, and appearance, and to reduce the risk of syneresis [8].

In general, food additives can be derived from natural or synthetic raw materials and used to improve food quality and extend shelf-life [16]. However, excessive use of artificial ingredients can potentially cause negative health effects, such as digestive disorders, allergies, and the risk of developing certain chronic diseases. Therefore, the use of safe natural additives with functional properties represents an important direction for meeting nutritional needs and increasing consumer acceptance of healthy beverages. This article aims to conduct a literature review of works that discuss the potential use of purple sweet potato flour as a natural stabilizer to improve the functional aspects of dairy products.

2. Objects and methods

A literature search was conducted using Scopus, ResearchGate, ScienceDirect, Springer, PubMed, and Google Scholar databases to ensure the inclusion of peer-reviewed research papers. The following keywords were used: dairy products, purple sweet potato flour, precipitation/syneresis, stabilizer, starch, and potential of purple sweet potato. The inclusion criteria focused on the issues related to the occurrence of syneresis in dairy products, the use of purple sweet potato (*Ipomoea batatas* L.) as a natural stabilizer, physicochemical properties, bioactive components, experimental studies, reviews, and laboratory analysis results related to physical stability (viscosity, syneresis, color, texture) in dairy products with added purple sweet potato flour. For this review, papers published no more than seven years ago were selected.

3. Milk and dairy products

Milk contains an animal protein that is important for meeting the nutritional needs of people. The essential amino acids in milk are highly digestible. Milk contains two main groups of nutrients, namely macronutrients and micronutrients [17]. Macronutrients are components found in large quantities in milk, including protein, fat, carbohydrates (primarily lactose), and water. Micronutrients consist of approximately 8–9 g/L of minerals, including Ca, P, Mg, Na, K, Fe, Se, and I. They also contain vitamins, lipophilic (A, D, E, and K) and hydrophilic ones (B vitamins and vitamin C), minerals, in various chemical forms, ions, organic salts, bound to proteins, and nucleic acids. In addition to the main nutritional composition of milk, there are various bioactive compounds, including peptides, probiotic bacteria, antioxidants, vitamins, specific proteins, oligosaccharides, organic acids, calcium with high absorption rates, conjugated linoleic acid, and other components, which can contribute to health [7,18–20]. The content of macro and micronutrients in milk from different animal species is presented in Tables 1 and 2.

The main minerals found in milk, such as Ca, Mg, K, Na, P, and Cl, are present in the form of mineral complexes and free ions. Such factors as pH, solids content, and temperature can affect the dynamic balance of these components. Additionally, the balance of minerals and casein content also has an impact. Soluble minerals in milk exist as free ions or bound to counter ions dispersed throughout the liquid phase. In contrast, insoluble minerals are mostly bound to casein micelles, such as calcium phosphate, which is also found within micelles. Milk also contains non-protein substances such as ions (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (phosphate, citrate, and lactate). In addition, there are also metal-ion complexes and calcium phosphate, which are generally insoluble, as well as amino acids bound to proteins. These ions interact with milk proteins, especially casein, through electrostatic forces between the positive charge of the free ions and the phosphoserine groups in the protein. However, these phosphoserine groups predominantly form bonds with calcium phosphate in colloidal form. About 1/3 of the calcium, 2/3 of the magnesium, 1/2 of the inorganic phosphate, and almost all of the citrate are present in the aqueous phase. At the same time, the remainder is bound to phosphorylated casein residues as calcium phosphate [21].

The dairy industry also produces several valuable and reusable by-products [22]. The nutritional composition of processed dairy products is presented in Table 3.

Some manufacturers develop new beverages using ingredients with high nutritional value, such as milk, grains, and yogurt, to obtain health benefits [24]. Milk and dairy products, such as yogurt, are considered nutrient-dense foods due to their content of protein, potassium, and other nutrients, including phosphorus, zinc, and B vitamins. Intake of such products may be associated with higher dietary quality [25]. The benefits of milk are well known to the public, making this product easy to accept widely. However, it should be noted that some commercial dairy products often contain artificial sweeteners. The purpose of incorporating additives into products is to improve their flavor. This strategy can have adverse health effects [26].

Table 1. **The content of macronutrients in milk from several animal species [20]**

Таблица 1. **Содержание макронутриентов в молоке нескольких видов животных [20]**

Nutrient	Animal species		
	Cow	Goat	Sheep
Proteins (g/L)	30–39	30–52	45–70
Fat (g/L)	33–54	30–72	50–90
Lactose (g/L)	44–56	32–50	41–59

Table 2. **The content of micronutrients in milk from several animal species [20]**

Таблица 2. **Содержание микронутриентов в молоке нескольких видов животных [20]**

Nutrient	Component	Animal species		
		Cow	Goat	Sheep
Mineral	Ca, mg/100 g	112–123	1330–197	159–242
	P, mg/100 g	59–119	79–153	124–175
	Mg, mg/100 g	7–12	14–36	16–25
	Na, mg/100 g	42–58	28–59.4	30–37
	K, mg/100 g	106–163	140–242	94–162
	Fe, mg/100 g	0.03–0.1	0.05–0.3	0.08–0.1
	Se, µg/100 g	1.7	1.1–1.7	1.7
	I, µg/kg	66.82	591.06	243.16
Vitamin	Thiamine	28–90	40–68	28–80
	Riboflavine	116–202	110–210	160–429
	Niacine (B3)	0.13	0.24	0.41
	Pyridoxine (B6)	30–70	7–48	27–80
	Folic acid (B9)	1–18	0.24–1	0.24–56
	Cobalamin (B12)	0.27–0.7	0.06–0.07	0.30–0.71
	Vitamin A	41	48	64
	Vitamin D	0.08	0.25	0.18–1.18
	Vitamin E	20–184		120
	Vitamin K	1.1–3.2		

Functional dairy products are prominent in the functional food segment of the market. Dairy products account for more than 40% of the total and are mainly produced from fermented milk [27]. The production of functional milks, such as yogurt, continues to increase due to their benefits for gut and digestive health [28]. Yogurt can be classified based on the type of additives used, fat content (fat-free, low-fat, normal), and texture (liquid, solid, stirred) [29]. Yogurt texture is a sensory aspect that significantly affects consumer acceptance. Poor gel firmness and syneresis are two texture defects that can occur in yogurt. Efforts should be made to prevent this [30].

4. Mechanism of syneresis in dairy products

Dairy products, such as yogurt, are prone to syneresis due to the fermentation process. Syneresis is a defect in food production processes, characterized by the separation of liquid from the surface of a gel. This leads to a denser and less creamy texture of the product. Syneresis can result in a negative change in consumers' taste sensations [31,32]. The stability of yogurt structure depends on the balance between attractive and repulsive forces between protein molecules, particularly casein, which form a gel network during the fermentation process [33]. The resistance of yogurt gel to syneresis depends on its stiffness and water-holding capacity [34]. The main components of yogurt, including protein (*casein and whey*), carbohydrates (*lactose*), milk fat, calcium, and lactic acid, play a crucial role in forming the gel structure and its stability.

4.1. Proteins

Milk proteins include casein and whey proteins. They have different structures and functions. Casein participates in the gel formation in dairy products, while whey proteins are a soluble fraction that remains in the liquid phase after casein coagulation. Both components complement each other in forming the texture and stability of processed milk products and cheese. There are several casein fractions, namely, β and κ, which interact with each other to form polymer complexes [20]. Casein is generally a random coil that forms micelles, serving as the basis for the gel structure in milk. Casein is relatively resistant to thermal denaturation due to the absence of a clear tertiary structure [35]. However, heat and acid

Table 3. **Nutritional composition of cow's milk and dairy products (per 100 g edible portion) [23]**
Таблица 3. **Химический состав коровьего молока и молочных продуктов (в пересчете на 100 г продукта) [23]**

Nutrient	Whole milk	Semi-skimmed Milk	Skim milk	Whole natural Yogurt	Whole greek yogurt	Skimmed natural Yogurt
Energy, Kcal	65.4/274	47.6/199	37/155	61.4/257	95	44.9/188
Proteins, g	3.1	3.5	3.9	4	8.78	4.3
Total lipids, g	3.8	1.6	0.2	2.6	4.39	0.32
Saturated fatty acids, g	2.3	1.1	0.09	1.5	2.39	0.11
Monounsaturated fatty acids, g	1.1	0.45	0.06	0.72	0.96	0.15
Polyunsaturated fatty acids, g	0.13	0.04	0.01	0.13	0.11	0
Cholesterol, g	14	6.3	2.6	10.2	17	1
Carbohydrates, g	4.7	4.8	4.9	5.5	4.75	6.3
Water, g	88.4	90.1	91	87.9	81.3	89.1
Calcium, mg	124	125	121	142	111	140
Iron, mg	0.09	0.09	0.09	0.09	< 0.10	0.09
Iodine, µg	9	8.6	11.1	3.7	42.3	5.3
Magnesium, mg	11.6	11.9	28.6	14.3	10.7	13.7
Zinc, mg	0.38	0.52	0.54	0.59	0.47	0.44
Sodium, mg	48	47	53	80	34	57
Potassium, mg	157	155	150	280	147	187
Phosphorus, mg	92	91	97	170	126	109
Selenium, µg	1.4	1.5	1.6	2	N.D	1
Thiamine, mg	0.04	0.04	0.04	0.04	0.06	0.04
Riboflavin, mg	0.19	0.19	0.17	0.18	0.24	0.19
Niacin equivalents, mg	0.73	0.71	0.9	0.44	0.23	1.2
Vitamin B6, mg	0.04	0.06	0.04	0.05	0.04	0.08
Folate, µg	5.5	2.7	5.3	3.7	N.D	4.7
Vitamin B12, µg	0.3	0.3	0.3	0.2	N.D	0.4
Vitamin C, mg	1.4	0.52	1.7	0.7	N.D	1.6
Vitamin A (retinol equivalents), µg	46	18.9	Traces	9.8	38	0.8
Vitamin D, µg	0.03	0.02	Traces	0.06	<0.01	0
Vitamin E, mg	0.1	0.04	Traces	0.05	N.D	Traces

treatment alter the solubility of calcium phosphate salts and trigger the redistribution of Ca^{2+} from the micelles to the serum phase. This can disrupt intermicellar associations and affect gelation and syneresis [36–38].

Based on available information, and -casein are involved in calcium binding through electrostatic interactions with colloidal calcium phosphate (CCP). When the pH drops from around 6.7 to 4.6 (the isoelectric point of casein), casein micelles lose their negative charge, so that the electrostatic repulsion between micelles weakens and they begin to aggregate to form a three-dimensional network (gel). Meanwhile, κ-casein forms "brushes" on the surface of the micelles that provide steric and electrostatic stabilization that prevents micelle aggregation at normal pH (~6.7) [18,30,39].

Acid gelation of milk proteins begins when colloidal calcium phosphate (CCP) starts to dissolve. This process begins when the pH decreases from 6.7 to 6.0 and continues until it reaches a pH value of 4.6 or lower. At this point, casein micelles become unstable because the calcium-phosphate bonds between submicelles break down leading to protein coagulation as a result of hydrophobic interactions. In addition, gelation also involves changes in the primary structure of protein and the formation of a three-dimensional network through aggregation. Aggregation occurs through the binding of protein chains via covalent or non-covalent bonds. The strength of these bonds plays a vital role in the quality and stability of acid gels [40,41].

Whey proteins include several fractions, among which is the most common (comprising about 50% of total protein). It is followed by, serum albumin, proteose-peptone, immunoglobulins, and metalloproteins such as lactoferrin, transferrin, or ceruloplasmin. Whey also contains enzymes such as lipase, protease, and phosphatase. Whey proteins are globular, spherical in shape, tightly folded, and completely soluble in milk. One of the most important functional properties of whey proteins is their ability to form a gel. Gelation occurs when whey protein undergoes denaturation due to heating or changes in pH, allowing the protein molecules to create a strong three-dimensional network structure [23,42,43].

Extensive research has shown that the denaturation of milk proteins affects gel formation and syneresis [44]. Heating, drying, or packaging under heating conditions can cause protein denaturation, which can potentially affect gel-forming properties. Denaturation of globular proteins results in the unfolding of the protein structure and exposure of previously hidden amino acid residues. In their native state, hydrophobic residues of globular proteins are located inside the molecule to avoid water. Denaturation results in the exposure of these hydrophobic residues, leading to the intermolecular hydrophobic interactions and subsequent aggregation [45].

Protein aggregation occurs through the formation of intermolecular cross-links, both covalent and non-covalent. During processing, intermolecular interactions may induce an ordered alignment of protein molecules, forming a fibrillar network similar to the structure of fibers [46]. During cross-flow filtration, the protein aggregates that form can accumulate and deposit on the membrane surface, creating a *fouling layer*. Uncontrolled aggregation can cause protein precipitation from the solution, while controlled interactions can affect gel formation, often reducing syneresis [45].

Heating milk above 70 °C causes thermal denaturation of proteins, particularly the disulfide bonds between (κ-CN), and (β-Lg), or the polymerization of whey proteins [44]. During the heating of milk, the tertiary structure of globular whey proteins breaks down, and free thiol groups are exposed. As a result, the thiol (–SH)/disulfide (SS) exchange reaction is triggered during the acidification of heated milk. These covalent bonds contribute to the strength of the yogurt gel [47]. At a temperature of 74 °C, remains in the micelles rather than dissolving and migrating into the milk serum, as it does under non-heated conditions. Heat treatment of milk causes aggregation of whey proteins and casein, resulting in the formation of a dense structure on the surface of casein micelles. This aggregation physically "blocks" or traps casein molecules, preventing their release into the serum phase [48].

4.2. Carbohydrates (lactose)

Lactose is the primary carbohydrate in milk, accounting for approximately 98% of the total carbohydrate content. At the same time, the remainder consists of small amounts of free glucose and galactose that are not bound within the lactose structure. In addition, the carbohydrate fraction of milk also contains other sugars in small amounts (less than 100 mg/L), as well as complex components such as glycoproteins and glycolipids [23,42]. Derivatives of lactose transformation, such as lactulose, lactitol, and lactobionic acid, are not found naturally in fresh milk. However, when lactose is heated at moderate temperatures, isomerization to lactulose (4-*O*-β-d-galactopyranosyl-d-fructofuranose) can occur through the Lobry de Bruyn–Alberda van Ekenstein reaction, which proceeds via the formation of the 1,2-enediol intermediate. As a result, the concentration of lactulose will increase according to the level of heat treatment. Increased levels of lactulose have the potential to be used as a quality indicator in milk processing [49].

The transformation of lactose to lactic acid during fermentation causes a decrease in pH (increased acidity) in milk. This change increases the polarity of the liquid phase and affects the solubility of mineral salts, including colloidal calcium phosphate (CCP) bound to casein micelles. During heating or fermentation, the decrease in pH causes the dissociation of CCP, releasing calcium (Ca^{2+}) and phosphate ions into the serum phase (*liquid*). The released (Ca^{2+}) blocks the ionic bonds that maintain the structure of casein micelles, thus affecting the stability of colloidal micelles. As a result, protein interactions become unstable and contribute to the formation of a gel network during subsequent fermentation, especially when the isoelectric point of casein is reached (around pH 4.6) [20].

Lactose can bind water and form non-covalent interactions with proteins, such as hydrogen bonds and van der Waals forces. These bonds can increase the viscosity of the serum phase and contribute to the formation of a smooth and stable gel structure. However, excessive heating and uneven carbohydrate distribution can disrupt the ionic balance. Protein-carbohydrate interactions become unstable, resulting in syneresis and the formation of insoluble complex precipitates [42,50]. Thus, the role of lactose in gel formation and stability is highly dependent on the balance of its interactions with proteins and calcium ions, as well as on its concentration and distribution in the system. This imbalance in the interactions not only affects gel structure but also has the potential to increase syneresis in fermented dairy products.

4.3. Fat

Milk fat is an essential nutrient-rich component [51]. More than 400 types of fatty acids have been identified, but most of them are present in very small proportions, namely, less than 1% [23]. Milk fat is a complex nutrient consisting mainly of hydrolyzable lipids (99%), plus a small amount of non-hydrolyzable lipids (1%). These lipids form spherical microglobules that are emulsified in the liquid phase of milk. This condition enables digestive enzymes to act on the fat globules, breaking them down or hydrolyzing them [52].

The casein network retains fat globules during the gel formation process. Milk proteins naturally adhere to the surface of the fat globules, and this interaction is crucial for the formation of the yogurt gel structure. The remaining water-soluble fraction, known as serum, consists of water, lactose, minerals, and unbound whey proteins dispersed in it. The presence of fat has a significant impact on the strength of yogurt gels. A higher fat content results in stronger gels and higher storage modulus (G') values. Conversely, fat separation weakens the gel structure [53]. To reduce the size of fat globules and prevent fat separation, homogenization can be performed at pressures of 15–20 MPa and temperatures of around 65–70 °C, either through single-stage homogenization or two-stage homogenization at pressures of 10–20 and 5 MPa. After heat treatment, the homogenization promotes denatured whey proteins to cover the surface of the casein micelles and integrate into the fat membrane, thereby increasing the firmness of the final product [30,53].

4.4. Calcium

Calcium is a significant mineral that not only serves as a nutrient but also maintains stability and forms the structure of casein micelles. Approximately 65–70% of calcium in milk is bound in colloidal form (*colloidal calcium phosphate*) within casein micelles. At the same time, the rest is insoluble (ionic Ca^{2+}, $CaHPO_4$, and Ca citrate) in the milk serum phase. In the aqueous phase, calcium (Ca) is present in free form associated with citrate, inorganic phosphate, and whey proteins. Approximately two-thirds of the total calcium is bound to casein in the form of micelles or calcium phosphocaseinate, which is associated with organic phosphates of phosphoseryl residues on the casein molecule [54]. Both are in dynamic equilibrium. Several factors, including temperature, pH, and ionic strength, can influence these molecules. Ca is thermodynamically balanced between the aqueous and micellar phases, depending on the chemical conditions [20]. The dissolution of colloidal calcium phosphate (CCP) during acidification increases serum calcium, thereby facilitating casein aggregation and the development of a gel network in yoghurt. This process also disrupts the internal structural properties of casein micelles as the pH decreases [41,55].

During the process of heating milk, some of the calcium that was initially soluble may become insoluble. In milk, calcium exists in two primary forms: the serum phase (*the liquid phase*) and the colloidal phase. In the serum phase, calcium is present as calcium ions (Ca^{2+}), calcium citrate, or calcium phosphate [44]. During heating, the solubility of calcium phosphate decreases, causing some calcium from the serum phase to transfer to the colloidal phase and form colloidal calcium phosphate. As a result, the levels of calcium and phosphate dissolved in the serum decrease, while the level of calcium phosphate in the colloidal phase increases. If heating is carried out at a moderate temperature, then after cooling, most of the transferred calcium can redissolve into the serum phase. However, when heated at high temperatures, this recovery is incomplete, resulting in an irreversible change in the calcium balance in milk [56]. From a health perspective, calcium plays a crucial role in the growth and development of children's bones, as well as in preventing osteoporosis in older individuals. Furthermore, adequate calcium intake can help reduce cholesterol absorption, control blood pressure, and maintain a healthy weight.

4.5. Lactic acid

Groups of microorganisms, such as lactic acid bacteria (LAB), have been widely used to produce fermented drinks, including yogurt as a processed milk product. Their probiotic, physiological, and survival qualities contribute to improving the nutritional value and sensory properties of the product. Compounds produced by LAB also play a role in inhibiting spoilage microorganisms [57]. During fermentation, lactic acid bacteria (LAB) convert lactose into lactic acid. The fermentation process causes physical changes, including changes in nutritional composition and the production of secondary metabolites. Decreasing the pH of milk from around 6.7 to ≤4.6 causes an acidification process that triggers protein coagulation and gel formation. Casein begins to lose its stability at pH 5.3–5.2, then precipitates and denatures when the pH reaches 4.7–4.6. To stop fermentation and prevent further acidification, yogurt must be immediately cooled to a temperature of <5 °C when the pH reaches ~4.6. Enzyme and microbial activity can cause the breakdown of components such as water, fat, protein, and other minor compounds or metabolites [57,58].

There are several methods to minimize syneresis in yogurt. The ingredients, such as milk powder, whey protein, casein, and gelatin, are often added for this purpose. Among all these additives, casein and gelatin are the most effective in preventing syneresis [30]. Additionally, yogurt processing stages, including homogenization, fermentation, storage duration, and cooling, also affect the final product.

5. Stabilizers

Stabilizers are essential food additives. They are usually added to dairy products to improve viscosity and sensory properties, slow down whey separation, and increase the total solids content. The addition of stabilizers can improve food's functional properties but also impact food's physical, chemical, and sensory properties. Some sources of stabilizers, such as *carboxyl methyl cellulose,* are synthetic. There is an increasing consumer demand for Halal and natural stabilizers [59].

6. Synthetic stabilizers

In the beverage industry, the quality and shelf life of products are significant challenges. Some consumers are willing to pay more for food with good sensory qualities [60]. To maintain the physical and sensory characteristics of beverages, synthetic additives are often used as additional ingredients [61]. The role of synthetic additives is to stabilize and preserve the taste, aroma, texture, and color of products, as well as to extend their shelf life.

There are several types of additives, but in general, they can be divided into four groups based on the method of production and origin. There are natural additives derived from plants and animals; synthetic additives designed to mimic the properties and functions of natural additives; natural additives modified with chemicals, and artificial synthetic additives [62].

Synthetic additives are widely used in the food industry to maintain and improve the quality of beverages. Despite their useful functions, excessive consumption of synthetic additives can negatively influence consumers' health. Although the use of synthetic additives is highly effective, there are studies showing that they can cause mutations and carcinogenicity in humans [63]. Baran et al. [64] stated that the use of synthetic stabilizers in mice was associated with effects such as obesity, impaired glycemic control, low-grade uric acid inflammation, and colon carcinogenesis. Such risks mainly arise when these substances are consumed at levels exceeding the threshold values set by food regulatory agencies. Therefore, controlling the amount and type of additives used is crucial to ensuring consumer safety and health.

7. The natural stabilizer derived from purple sweet potato flour *(Ipomoea batatas L)*

The sweet potato is a type of tuber that can grow in tropical and subtropical climates, demonstrating high adaptability [65]. The purple sweet potato sold on the market is widely used for fresh consumption and as an ingredient in processed foods [18]. The nutritional and functional values of fresh purple sweet potato are shown in Table 4.

Table 4. **Nutrient content in 100 g purple sweet potato [66]**
Таблица 4. **Содержание питательных веществ в 100 г фиолетового батата [66]**

Category	Nutrient	Content
Nutritional and calorie	Calorie, kcal	86
	Carbohydrate, g	20.12
	Protein, g	1.57
	Fat, g	0.05
	Vitamin A, SI	
	Vitamin C, mg	2.40
	Ca, mg	30
Compounds	Carbohydrate	12.64
	Reducing sugar, %	0.30
	Fat, %	0.94
	Protein, %	0.77
	Water, %	70.46
	Ash, %	0.84
	Fiber, %	3.00
	Vit. C, mg	21.43
	Anthocyanin, mg	110.51
	Beta carotene, mg	–

The purple sweet potato is highly susceptible to oxidation and discolouration during processing, distribution, and storage. Drying is one of the processes used to stabilize bioactive compounds in it [67]. To extend shelf life, the purple sweet potato can be processed into flour. Purple sweet potato flour has several advantages, including its us as a substitute for other flours, greater storage stability, and availability of raw materials regardless of the harvest season. Additionally, this flour can be easily modified to maintain its bioactive properties, thereby enhancing the functional value of the product [68]. Purple sweet potato flour can also be used as an additive in various food products such as baby food, pasta, and fried foods [5]. In the food industry, flour serves as the primary thickening agent in sauces, soups, snacks, and bakery products [69]. Factors that influence the quality of processed products are physicochemical properties such as water absorption, solubility, and viscoelasticity. Several studies have shown that the water absorption index of sweet potato starch is similar to that of commercial wheat flour. The physicochemical characteristics of purple sweet potato starch are presented in Table 5.

7.1. Starch

Starch is the main component in the purple sweet potato [70]. In developed countries, the sweet potato (*Ipomoea batatas*) is the primary source of starch production [59]. Starch consists of two parts, namely digestible and indigestible starch (resistant starch). Resistant starch is not broken down in the small intestine but can be fermented in the large intestine in small amounts or completely. Although not digested, these starches provide health benefits, including reducing the risk of cancer and colon cancer, preventing the formation of gallstones, controlling hypoglycemia, and promoting the absorption of minerals in the body [18].

Starch has been widely used as a thickener, stabilizer, and gelling agent in various applications. Its high water holding capacity enhances strong interactions with milk proteins [71]. The starch used in yogurt production reduces defects, including surface-related ones, and improves texture [59]. Additionally, starch can improve flavor. Corn starch has long been used as a thickener and as a fat replacer in yogurt. Recently, other types of starch, such as kudzu starch, tapioca starch, water chestnut starch, and potato starch, have also been used [30].

Physical and chemical modifications are often carried out to improve the functional properties of natural sweet potato starch. A commonly used method is gelatinization [72,73]. Starch mixed in the solution requires heating for its gelatinization or expansion of its properties. Heat treatment aims to achieve a gel state with the consistency of a thick solution [74]. This process can increase water absorption and granule swelling [75]. It has been shown that gelatinized starch can improve food products' stability, texture, and hydration characteristics [76]. Heating food products to high temperatures in order to form gels, may limit their use in certain types of food, as this process may alter the properties of the products [74].

7.2. Fiber

In addition to meeting your fiber needs, dietary fiber has functional and nutritional benefits. Fiber can be soluble and insoluble. Soluble fiber can increase viscosity, form gels, reduce glycemic response, and lower cholesterol levels. In contrast, insoluble fiber, increase fecal volume and intestinal transit. The nutritional properties of fiber can affect physicochemical characteristics of products, such as water-holding capacity, viscosity, interaction with other molecules, and fermentation [77]. In dairy products, especially probiotic products, fiber is widely used as a multifunctional additive. The stabilizing effect of fiber can change with different formulations in dairy products such as ice cream and beverages [78]. Fiber can bind water, slowing down its free flow in the gel structure. This process leads to water binding and a decrease in syneresis [14].

7.3. Anthocyanins

Purple sweet potato flour is rich in anthocyanins. Anthocyanins are natural colorants with various bioactive properties. Anthocyanins' molecules provide purple sweet potato flour with color and, antioxidant

Table 5. **Physicochemical characteristics of purple sweet potato starch [66]**
Таблица 5. **Физико-химические свойства крахмала из фиолетового батата [66]**

Characteristics	Unit	Content
Physico-chemical characteristics of starch	Moisture content, %	5.84
	Protein, %	3.21
	Starch, %	64.63
	Bulk density, mg/l	0.43
	Anthocyanin content	19.75
	Water absorption index, ml/g	1.69
	Water solubility index, g/ml	17.36
	Hot viscosity, cp	—
	Cold viscosity, cp	7.84
Amylographic characteristics of starch	The beginning temperature of gelatinization/SAG, °C	75.75
	Maximum viscosity, cp	5523
	Temperature of maximum viscosity, °C	—
	Viscosity at temperature 95 °C	4332
	Breakdown viscosity, cp	3049
	The viscosity of cooling at a temperature of 50 °C, cp	3493
	Setback, cp	1244
	Stability of pasta, cp	—
Amilose and amilopektin content	Amylose content, %	43.78±0.56
	Amylopectin content, %	44.24±4.71

properties [79,80]. From a sensory point of view, anthocyanins in the purple sweet potato are considered safer than synthetic colorants, so consumers prefer them. Anthocyanins can also act as natural water-soluble colorants. Anthocyanins can produce attractive colors for food, such as blue, red, and purple. The extraction of anthocyanins from purple sweet potato flour offers a natural alternative, a simple extraction process, and lower cost efficiency [67].

Anthocyanins in the purple sweet potato are more stable to heat and UV light exposure than other fruits and vegetables, such as strawberries, apples, and cabbage, due to their high degree of acetylation. Anthocyanins from the purple sweet potato have greater resistance to gastrointestinal conditions compared to less complex anthocyanins, such as those found in red wine. Therefore, these beneficial characteristics highlight the potential use of the purple sweet potato as a source of natural food ingredients [81].

7.4. Flavonoids

Many studies have attempted to replace synthetic additives containing antioxidants with natural ingredients. Polyphenols and flavonoids are secondary metabolites in plants that have many benefits [63]. Flavonoids can be found in the purple sweet potato, containing anthocyanin compounds and glucose-bound quercetin (glycosides) [57]. These compounds are antioxidants capable of scavenging free radicals. In addition, they provide hydrogen atoms, electrons, and chelate metal cations. Flavonoids act as antioxidants by transferring hydrogen atoms to free radicals. Therefore, the higher the flavonoid content, the greater the antioxidant capacity to transfer hydrogen. Based on in vitro research, flavonoids in plants have antioxidants that exhibit antioxidant activity comparable to that of synthetic antioxidants. However, this requires commercial methods and developments [63].

Purple sweet potato flour is a valuable ingredient in food processing and demonstrates the potential of this plant for broader applications. Its functional properties, such as water absorption, can impact the texture of final products. The use of purple sweet potato flour can also prevent losses and can be used in the production of various food ingredients. In addition, it also serves as a source of energy and minerals, providing products with a sweet taste and attractive color. The nutritional-value of purple sweet potato flour plays a vital role in the development of various food formulations [65].

8. The production process of flour from the purple sweet potato

We can see the production process of flour from the purple sweet potato in Figure 1.

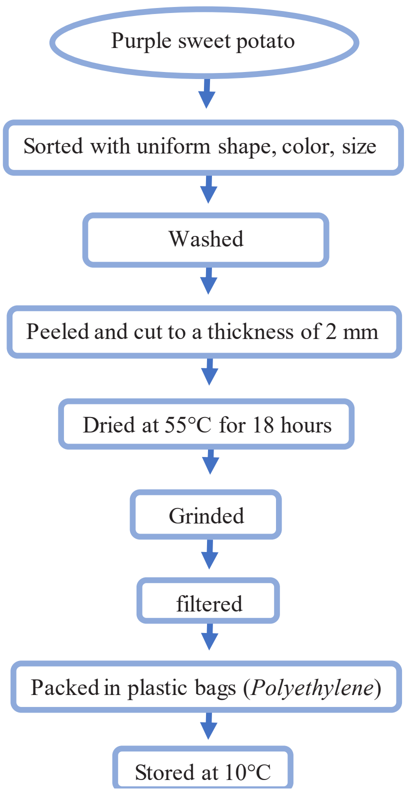

Figure 1. **Schematic diagram of flour production from the purple sweet potato [82]**
Рисунок 1. **Процесс производства муки из фиолетового батата [82]**

Before adding purple sweet potato flour to dairy products, it should be heated at a high temperature until gelatinization occurs. The gelatinization process is expected to result in water binding and reduced syneresis in dairy products. This process is an essential step in breaking down the starch structure. The starch granules absorb water during this process, which initiates the swelling phase. Heating accelerates the swelling of starch granules and breaks their structure, accelerating gelatinization [75]. The stages of processing purple sweet potato flour before starch gelatinization can be seen in Figure 2.

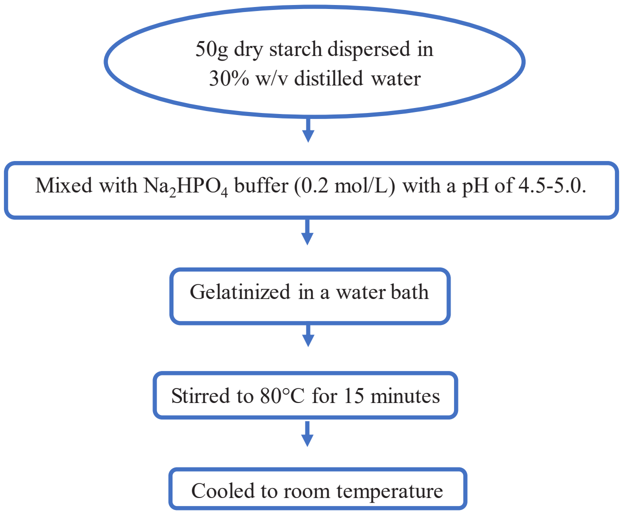

Figure 2. **Schematic diagram of starch gelatinization [83]**
Рисунок 2. **Стадии клейстеризации крахмала [83]**

Physical treatment of starch is widely used, one type of which is a heat treatment with limited water content. Moist-heat treatment is a hydrothermal method of physical modification, in which starch is heated at a temperature exceeding its gelatinization point (approximately 80–120 °C) with a limited water content of 10–35 % for 15 minutes to 16 hours. This technique is environmentally friendly, safe, and cost-effective for improving starch characteristics. Several studies have reported that an increase in temperature leads to an increase in the swelling capacity of starch. Starch granules heated at the initial temperature will swell due to weak hydrogen bonds in the amorphous region. This is caused by stronger interactions between starch polymer chains, including amylose-amylopectin, amylopectin-amylopectin, and interactions between starch and lipids. This also indicates an increased water-binding capacity in starch granules [65,84]. The application of purple sweet potato flour in dairy products is illustrated in Table 6.

9. Factors causing syneresis

The main components of the purple sweet potato, including starch, fiber, and anthocyanins, can impact the level of syneresis in dairy-based products. Mechanisms that contribute to syneresis include the concentration of additives (*such as starch and fiber*), changes in acidity (pH), and the protein and fat content in the system. In addition, heat treatment, storage temperature, and storage duration also play an essential role in determining the physical stability of the product [87,91].

9.1. Quantity of ingredients

In general, syneresis in yogurt can be reduced by adding approximately 14 % (w/w) total solids to the product [92]. Increasing the total solids and protein content can strengthen the gel structure and increase the gel's water-holding capacity [53]. The addition of purple sweet potato flour can improve consistency, viscosity, and taste because the fiber/solids content can bind water in yogurt [81]. The concentration of flour added must be considered. Adding too much flour can make the product overly thick, create a heavy mouthfeel, and produce a distinct *aftertaste* reminiscent of potatoes or other tubers. Conversely, if the flour concentration is too low, the stabilizer will be ineffective, and syneresis will still occur [30,81,89].

The addition of purple sweet potato flour can increase water-binding capacity due to its content of cellulose, lignin, pectin, hemicellulose, and fiber, among other compounds. The amount of fiber can reduce the pore size in the gel matrix, thereby retaining water [87]. KIlinç et al. [87], as presented in Table 6, compared the effect of adding freeze-dried sweet potatoes on the nutritional quality of yogurt sets. The results showed that adding 2 % purple sweet potato flour was more beneficial because it contained higher levels of cellulose, lignin, pectin, and hemicellulose than orange sweet potato flour.

Table 6. **Application of purple sweet potato flour**

Таблица 6. **Применение фиолетового батата**

Dairy Products	Result	References
Ambon banana yogurt	The addition of 2% purple sweet potato flour to Ambon banana yogurt ensures the best quality. Purple sweet potato flour has the potential to be a stabilizer for yogurt production.	[14]
Ice cream	Adding purple sweet potato flour affected the water and anthocyanin content but didn't change the antioxidant activity of the ice cream. A ratio of water to purple sweet potato flour of 2:8 was optimal for high water content, standard overrun, anthocyanin content, and antioxidant activity.	[85]
Greek yogurt	Fortification with purple sweet potato flour reduces syneresis, increases water retention capacity, inhibits post-acidification processes, increases viscosity, elasticity, and hardness, and improves color stability during storage. Adding 4% sweet potato flour makes the yogurt firmer and more elastic. These results indicate that purple sweet potato flour is a multifunctional natural ingredient.	[86]
Stirred yogurt	Purple sweet potato flour can provide different colors, increase water retention capacity, and reduce water activity. In general, the addition of purple sweet potato flour improves the microstructure of yogurt, and the addition of 4% and 6% of it makes the yogurt denser and softer. These results indicate that purple sweet potato flour can be used in the food industry to enhance functionality and serve as a natural coloring agent, stabilizer, emulsifier, and thickener in dairy products.	[81]
Set yogurt	The addition of 2% purple sweet potato to yogurt resulted in a dry matter content of 8.45%, water holding capacity of 50.90%, total phenolics reaching 2.64 mg GAE/g, and DPPH radical scavenging activity of 112.97%. The yogurt contained the highest mineral content of potassium (2,765,987.42 ppb), followed by sodium (250,078.00 ppb) and magnesium (203,691.47 ppb). The texture of the yogurt also improved with the addition of 2% purple sweet potato. It was characterized by the highest firmness value of 229.07 g, consistency of 2,690.00 g, cohesiveness of –81.70 g, and viscosity index of –290.54 g. The addition of sweet potato to the yogurt samples had a significant impact on the pH, which can affect the final quality of the product.	[87]
Goat milk yogurt with the addition of pineapple and purple sweet potato	Water binding capacity, solubility, and viscosity reached 10.73%, 3.08%, 90%, and 352.93%, respectively, along with a decrease in syneresis by 15.73% compared to goat milk yogurt without the addition of fruit and sweet potato.	[88]
Yogurt	The sensory evaluation of the sample with 2% flour scored highly. The fat content of each sample was similar. Physicochemical parameters and water holding capacity (WHC%) showed significant differences. Scanning Electron Micrograph (SEM) results of yogurt enriched with purple sweet potato flour showed a denser structure, with lumps of flour that appeared to be attached to the gel matrix. The results obtained in this study show that the sweet potato can contribute to the production of cohesive and dense yogurt and can be used as a substitute for industrial stabilizers.	[8]
Non-fat set yogurt	The addition of 1% starch reduced syneresis and increased the firmness of yogurt. Differences in amylose content in starch led to variations in yogurt quality. Yogurt had higher viscosity with the addition of corn and tuber starch. Long storage time can change the characteristics of yogurt, leading to syneresis (wheying-off). However, the pH didn't change. Sensory properties were different in the yogurt with added starch and the control sample. The results showed that yogurt with the addition of tuber or chickpea starch was the most promising.	[89]
Ice cream	Steaming was used to retain anthocyanins in the sweet potato. The results showed that in terms of sensory properties (aroma, taste, texture, and color), it was accepted by 26 panelists.	[90]

9.2. pH and acidity

Probiotic dairy products, such as young yogurt, experience a gradual decrease in pH during the fermentation process. Technological aspects, including pH and acidity, during yogurt processing are essential parameters for assessing product quality. Increased milk acidity can cause casein instability when the pH drops below the isoelectric point, resulting in syneresis [93]. Dairy products will curdle and form a three-dimensional protein network in which whey is trapped [94].

Purple sweet potato flour has a significant impact on the pH of dairy products. Increasing the amount of sweet potato flour causes a decrease in pH [8,95]. As shown by Kilinc et al. [87] as presented in Table 6, acidity also plays a role in forming structure and syneresis. At a pH of 4.0–4.6, the viscosity of the product increases and syneresis decreases, while at high acidity levels, below pH < 4.6, the water-binding capacity is very weak. The addition of purple sweet potato flour to dairy products reduces the pH of yogurt due to compounds in its structure, which causes a decrease in syneresis and an increase in water-holding capacity (WHC).

The starch contained in purple sweet potato flour is thought to increase the availability of carbon source nutrients for lactic acid bacteria (LAB). The increase in acidity in yogurt is caused by the conversion of lactose to lactic acid, which occurs more quickly due to higher LAB proliferation and viability [14]. Additionally, the increase in viscosity and water-holding capacity (WHC) of starch in purple sweet potato flour can reduce osmotic stress and help maintain a medium moisture level. This results in a more stable fermentation environment for LAB growth [8]. Phenolic compounds in purple sweet potato flour have antimicrobial activity, damaging the protective layer of cells and disrupting the functioning of microbial enzymes. Proper formulation can support the growth of probiotic LAB [81,87].

9.3. Protein and fat content

In general, the denaturation of milk proteins, particularly β-lactoglobulin and α-lactalbumin, is a crucial step in the yoghurt-making process. However, denaturation can disrupt the protein gel structure, triggering syneresis. The addition of stabilising agents such as starch increases the hydrophilic properties of proteins, thereby enhancing their ability to bind water [14]. Purple sweet potato flour offers a combination of starch, fibre, and anthocyanins that serve as both thickening and stabilising agents in protein systems, thereby increasing the viscosity and water retention of products [96]. Modified purple sweet potato particles can form Pickering stabilisers at the oil–water interface. This can reduce coalescence and improve the stability of protein-based emulsions during heat treatment and freeze-thaw [37]. Non-covalent interactions between purple sweet potato anthocyanins and proteins can enhance colour stability and influence the protein network structure, ultimately affecting the final texture of the product [81].

The composition and properties of fat have a significant impact on food structure and the perception of fat texture. High fat content can affect yogurt quality, including increased viscosity, density, a creamy texture, elasticity, and hardness. Reducing the fat content in dairy products can compromise texture, which in turn affects taste and aroma. Fat is essential for taste perception because flavour compounds in food are soluble in fat. Therefore, the amount of fat in a product is crucial for the final quality of the product [18]. Fat substitutes, such as modified starch or inulin, can alter rheological properties by mimicking the function of fat globules or affecting water-binding capacity. Homogenization alters the size and distribution of fat globules, resulting in changes in viscosity, texture, and stability [53]. Purple sweet potato flour has a low-fat content. According to El Attar et al. [8] (Table 6), the addition of sweet potato flour (control, 0.5, 1, 2, and 4 g/100 g milk) resulted in a fat content of 2.87–3.50 g/100g, demonstrating no significant effect on fat content.

9.4. Heat treatment

Heating milk at high temperatures can cause denaturation of whey proteins, which affects the gel strength of yoghurt [47]. In a study by Gao et al. [97], the texture and rheological properties of fermented milk were affected by heating (55–85 °C for 25 seconds), which impacted the final properties of the fermented milk. Treatment below 65 °C increased gel strength, firmness, and viscosity due to the formation of moderate aggregation and stable microgel bonds. Conversely, heating above 65 °C reduced texture quality due to the formation of large aggregates (~46–63 µm) that produced coarse and undesirable grains. Purple sweet potato flour has a high starch content. During the heating process, the starch undergoes partial gelatinisation, which increases the viscosity of the yoghurt matrix and helps maintain gel stability [62,71]. Starch particles and fiber from the purple sweet potato can act as natural Pickering stabilizers, which protect the protein structure during heating [96].

9.5. Storage temperature

Storage temperature is one of the factors that determines the stability of yogurt and other dairy products. Arab et al. [30] found that at higher storage temperatures, microbial activity and changes in protein structure due to partial denaturation can cause a decrease in water-holding capacity (WHC), thereby increasing the likelihood of syneresis. This process is exacerbated by the degradation of the gel network formed during fermentation, which becomes more fragile due to temperature fluctuations. Gao et al. [97] emphasize that maintaining a constant, low storage temperature is crucial for preserving the texture and stability of fermented dairy products. These findings provide further insight into the mechanisms underlying the formation of fermented milk quality after heating, and offer new perspectives for addressing potential texture defects in fermented milk products during storage in environmental conditions.

The content of purple sweet potato flour can increase viscosity and strengthen the protein gel structure. The components of purple sweet potato flour can bind water and milk proteins, forming a denser and more stable three-dimensional network during storage at low and fluctuating temperatures [81]. Saleh et al. [89] (Table 6) stored differently treated samples at 4 °C before conducting sensory and physicochemical quality tests. Cota-López et al. [98] also confirmed that the addition of retrograded starch to fermented milk products can maintain gel stability despite variations in storage temperature. Thus, the use of purple sweet potato flour as a natural stabilizer can be an effective strategy for preserving the microstructure of milk gel and preventing an increase in syneresis due to temperature changes during storage.

9.6. Long storage

Storage duration is one of the primary factors influencing the physical stability of processed dairy products, such as yogurt. Physical defects in yogurt can be observed after it has been processed and stored for a specified period [30]. Storage duration can accelerate syneresis due to changes in protein structure and a decrease in water-holding capacity (WHC). This is caused by the post-acidification process and the rearrangement of protein networks during storage. This process causes syneresis [99]. Experimental studies also report that during cold storage, post-acidification 'increases the size of casein particles,' contributing to changes in gel structure and a decrease in WHC [100]. The yogurt studied by Anwar et al. [101] had optimal fermentation times of 6 hours for sheep's milk, 7 hours for cow's milk, and 5 hours for the mixture of both. To maintain quality, the optimal storage period was up to 14 days at 4 °C. Sheep milk yogurt excels in terms of acidity, bacterial count, water-binding capacity, and taste, making it suitable for use in probiotic products. The longer the product is stored, the greater the chance of protein gel structure degradation.

The second cooling process is carried out in stages over 12 hours to improve the yogurt's quality. Cooling too quickly can cause a weak gel structure and increase the likelihood of syneresis during storage. Meanwhile, in the production of drinking yogurt, the fermented product is stirred, then diluted, and stabilizers are usually added to maintain its stability [53]. The addition of 4–6% purple sweet potato powder (lyophilized powder) to yogurt contributes to a denser, more compact gel network and reduces the rate of syneresis during 30 days of storage. Bioactive compounds in purple sweet potato flour can interact with milk proteins, thereby maintaining the product's microstructure stability during long-term storage [81].

10. Development prospects

The prospect of developing purple sweet potato flour as a natural stabilizer in Indonesia is promising. Indonesia is a tropical country with fertile soil and diverse natural resources. Based on its resource potential, Indonesia has abundant food availability [102]. After China, Indonesia occupies an essential position as the leading producer of the purple sweet potato [66], especially when compared to other crops. The purple sweet potato has a more expansive production geography, adaptability, and short production cycle; in addition to high nutritional value, it also has sensory advantages in flesh color, taste, and texture [103].

The cultivation of purple sweet potato can be done in various ways. The majority of cultivation is carried out on dry land, with attention to soil and water management as the key to success [66]. Based on the results of field research, the most common varieties of the sweet potato-are white, yellow, and orange. After the discovery of the purple sweet potato, it attracted public attention. The purple sweet potato has good prospects because it's in high demand. Apart from having an attractive color, the purple sweet potato also has health benefits [102]. This development is in line with the global trend of increasing interest in functional foods. Consumer demand for the use of natural and organic ingredients is rising. Consumer awareness of using natural ingredients, minimal processing, and the avoidance of negatively perceived ingredients, such as allergens or additives, is growing. This creates market opportunities for processed food products that use purple sweet potato flour as a base [104].

Developing Indonesia's purple sweet potato processing industry can positively impact the community's economy and the livelihoods of sweet potato farmers. In addition to increasing food diversification, the development of the purple sweet potato flour industry can also create jobs and provide benefits in both health and the economy [105]. In 2022, the Indonesian Ministry of Agriculture initiated a purple sweet potato planting program spanning 2,000 hectares (ha) across several locations. This program aims to stimulate the economy through the food potential of rural products, such as purple sweet potato flour [66]. The high demand for the sweet potato as a raw material for the food industry will increase farmers' income and promote greater efficiency in the purple sweet potato production. The purple sweet potato in South Korea and Japan has become a healthy food trend due to its good nutritional value [106].

The utilization of the purple sweet potato in Indonesia as a functional food is still limited. The sweet potato is generally consumed by frying or boiling, and in the form of chips and traditional foods such as *timus* [107]. This is due to the lack of public knowledge regarding the purple sweet potato processing. This situation can be attributed to the lack of purple sweet potato processing technology and the increasing consumer demand for suitable products. Therefore, the government needs to provide strong support for the processing industry in order to stimulate the development of the products from the sweet potato [66]. In developing countries, millions of people consider the sweet potato as an essential food source [8]. Therefore, the use of the purple sweet potato should be achieved through product diversification. The product diversification process is expected to produce foods that are nutritious, attractive, and have added value with the use of simple technology [107]. Some efforts can also be made to promote the purple sweet potato. One approach involves providing the public with information on the benefits of the purple sweet potato through promotions and conducting field practices on the utilization of the purple sweet potato [105].

11. Conclusion

Dairy products such as yogurt often undergo syneresis, resulting in the separation of liquid and solids, which therefore requires the use of stabilizers. Purple sweet potato flour contains starch that easily absorbs water and swells, making it a suitable natural stabilizing agent. In addition to starch, the purple sweet potato also contains fiber, protein, sugar, minerals, and anthocyanins, which play an essential role in strengthening gel structures and preventing syneresis. The anthocyanins in the purple sweet potato can also act as antioxidants, adding value to the final dairy product. These components can bind with milk proteins and fats, forming a more stable gel structure. Other factors such as heat treatment, storage temperature, and storage duration also affect the physical stability of the product. The prospects for developing the purple sweet potato in Indonesia are promising due to its high agronomic potential, good nutritional value, and opportunities for use as a natural raw material in the functional food industry.

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