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Review article

Wheyless cheese: An alternative method to reduce the environmental hazards of Lighvan cheese production

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A B S T R A C T

Cheese is one of the dairy products that have an important role in a family's food basket. Different types of cheese are produced in the world. In Iran, Lighvan cheese is very popular among people due to its special flavor, but the produced whey from this type of cheese is discarded. Due to its high biological oxygen demand (BOD), whey has a detrimental effect on the environment, and providing solutions to reduce these effects can pave the way for the cheese industry, especially Lighvan cheese. One of the proposed solutions is to produce wheyless cheese. Some studies have been done in this field, if the method of producing cheese without whey does not reduce the unique features of Lighvan cheese it could be a very suitable option for producing this type of popular cheese. So, in this study, we attempt to provide a comprehensive overview of various aspects of Lighvan cheese, environmental disadvantages of whey, and methods of reduction of its destructive effects including the production of wheyless cheese.

Keywords: Dairy; Environment; Green technology; Sustainable

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1. Introduction

The food section is one of the most important productive and economic sections in the world. However, it is an important source of environmental impacts (Gonzalez-Garcia et al., 2013). In surveys conducted between different foods, meat (beef, pork, chicken) and dairy (cheese, milk, butter) products have the most impact on environmental pollution (Notarnicola et al., 2017; Van Middelaar et al., 2011; Palmieri et al., 2017).

Dairy products are a significant source of daily nutrients for human body and are recommended as a part of a healthy and balanced diet. However, their production has many environmental effects (Palmieri et al., 2017). Nowadays, in dairy products, cheese is in increasing demand and after it, milk is the most consumed dairy product (Gonzalez-Garcia et al., 2013; Roos et al., 2016; FAO, 2017). Cheese, with a wide range of different types of quality and, flavors is one of the oldest and most consumed foods and dairy products because of its high protein and calcium content. In addition, cheese helps to absorb calcium and generally has fewer digestive problems than other dairy products (Karaman & Akalin, 2013). In Iran, there are several types of cheese, the most popular of which are Feta and Lighvan. Cheese is traditionally produced from dehydration of coagulated milk; the separated liquid is called whey. Consumption and production of cheese around the world is increasing at a rate of 2% per year. As a result, whey production is also increasing and it is reported that the major producers of whey are the EU and US (FAO, 2017; Stiles, 2012).

In most cases, whey is not used, resulting in loss of high-value nutritional compounds including whey proteins and minerals. Also due to the high content of organic matter with high biological oxygen demand (BOD) and chemical oxygen demand (COD), it causes serious environmental pollution (Genzalez, 1996). Therefore, in this study, a review of studies on the environmental effects of whey and methods to reduce the destructive effects or reduce the volume of produced whey including the production of cheese such as Lighvan cheese with about 25% whey is discussed.

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1.1. Lighvan cheese and its characteristics

Lighvan cheese is a traditional semi-hard cheese with 60% moisture that is produced in Lighvan village in the southeast of Tabriz. Lighvan cheese is usually made from 70-80% sheep's milk and about 20 to 30% of goat's milk without the use of a starter. Iranians prefer this cheese because of its extremely natural taste and flavor (Ehsani et al., 2018; Edalatian et al., 2010). Sheep's milk, due to its higher fat, protein and dry matter, provides Lighvan cheese with a higher amount of nutritious substances in comparison with cow's milk cheese and, as a result, it tastes better than it (Ehsani et al., 2018).

To produce Lighvan cheese after adjusting the temperature of raw milk in the range of 35ºC, rennet is added to it and after an hour when the curd formation is complete, whey is separated by cutting the curd. The rest of the whey is removed by applying pressure and after salting; at the end, the cheese curds are packed and placed in a cool place for about 3 months to ripen. Since the production of this cheese is done on workshop scale, the resulting whey is not collected and processed and so enters the waste water system. Whey, depending on the type of consumed milk, makes up 75 to 85% of milk volume and it has a pH of about 5-6.5 (Siso, 1996; Argenta & Scheer, 2019), 6- 10 gr per liter of protein (Jelen, 2003; Sommella et al., 2016), 3-6 gr per liter of fat, 46- 52 gr per liter of lactose and 2.5-4 gr per liter of minerals (Rayan & Walsh, 2016; Guo & Wang, 2019).

Table 1 shows the average composition of cow, sheep, and goat whey (%w/v). As can be seen, the amounts of all compounds including lactose, protein, fat and dry matter in sheep and goats are higher than cows' whey, so, from an environmental point of view, it can be said that producing whey has more environmental problems than cow's milk. Many studies have been done on whey and Lighvan cheese, but the environmental effects of whey made from Lighvan cheese and the ways to reduce it have not been considered.

Table 1. The average whey of cow, sheep and goat (%w/v) (Pires et al., 2021).

	Cow whey	Sheep whey	Goat whey
Total solids	6.0-7.0	7.6-10.5	7.07-10.8
Lactose	4.2-5.0	4.3-6.1	5.02-6.7
Proteins	0.7-0.9	1.6-1.8	0.63-1.2
Fat	0.1-0.8	1.2-2.5	0.84
Minerals	0.5-0.6	1.0-1.8	0.57
pH	5.6-6.3	5.3-5.9	6.34

1.2. Whey and environmental studies

Global production of whey by diary industries reaches millions of tons, but the effective use of this material is not well developed. Global whey production is estimated at 115 million tons per year. Approximately 47% of whey produced is released into the environment (Illanes, 2011) and 53% of it is used and processed. Whey has several uses. This valuable byproduct can be used as a substrate in fermentation processes. Several whey products have been produced using various fermentation techniques such as singl-cell protein (Ghaly & Ben Hassan, 1995), ethanol, organic acids (Tangos & Ghaly, 1999), biopolymers (Fitzpatrick et al., 2001), antifreeze, and biodegradable plastics (Ghaly et al., 2001).

Although some whey is used in industry, in many cases it is spread on farmland. These whey disposal methods are associated with devastating environmental consequences because of the high level of sugar and protein in whey that pollutes the soil and nearby waterways. Some estimates show that whey discharge is 175 times more harmful to the environment than the discharge of unrefined human wastewater (Aguirre-Villegas et al., 2012; King & Weedon, 2019). In one study, the environmental impact of cheese production was investigated by Canellada et al. (2018), in that study the environmental impact of a cheese factory located in a region of northwestern Spain is analyzed by the life cycle. The data obtained directly from these facilities that was related to one-year' activity, all the influential factors in cheese production including raw water, electricity, energy, cleaning products, packaging materials, transportation, solid, liquid and gas wastes were considered (Sar et al., 2021). The results showed that the environmental impact of cheese production mainly originates from the production of raw milk; in contrast, the production of packaging materials and other non-dairy products rarely affect in the environment. In addition, the average carbon effect of produced cheese in the facility was calculated and analyzed, which showed that, as a result of milk production, they have the highest share of pollution in subsystems. Finally, previous studies on the environmental performance of cheese production around the world were reviewed and compared with the results obtained in that paper. According to the analyzed data, it was found that fat content and dry matter are determining factors for the carbon effects of cheese while the scale of cheese production and geographical area have very little effect.

In another study, Aguirre-Villegas et al. (2012) conducted research on life cycle impact assessment (LCA) and the development of practical methods for processing cheese and whey. In this study, life cycle assessment methods were used to estimate the global warming potential (GWP) and energy consumption intensity (EI) resulting from the production of cheese and whey powder in the US state of Wisconsin. In this process, two methods were used, the first method is the traditional method of cheese production and whey is discarded and in the second method, none of the leftovers of cheese production enters the environment and from the rest of the whey, other food products are produced through a multi-stage system. The results show that the two indicators, GWP and EI, for cheese and whey powder are strongly influenced by the choice of methods. In other words, the EI production of one kilogram of cheese in the first method increases from 7.1 megajoules to 19 megajoules in the second method, so the GWP value of cheese production in the first method changes from 0.46 to 1.3 kg of carbon dioxide per kg of cheese production in the second method. In other words, if it is decided that the production of cheese has no waste and all its residues are used to produce other foods, the amount of energy consumption and production of carbon dioxide gas is much higher than the current situation which requires expert analysis and big decisions.

In research by Kia Deliri et al. (2017), the treatment of whey using membrane bioreactor was studied and analyzed. The reason for this choice is the reliability and simplicity of the method and the low cost of biological processes for whey treatment. One of the problems of membrane processes is membrane fouling. One of the most effective ways to reduce membrane fouling is aeration, which uses computational fluid dynamics as a powerful tool to study the flow conditions of membrane bioreactors. This study, investigates the hydrodynamic effect of two-phase flow on the degree of fouling of the polymer membrane made in the laboratory at five different aeration rates and three different geometries. By increasing the

aeration rate, the amount of tension due to biphasic flow on the membrane surface increases and these tension changes in aeration is less obvious. COD removal efficiency also increases with increasing aeration. In addition, the effect of baffle was investigated in this study. Baffles are components of chemical reactors or heat exchangers that change or stop the direction of fluid (Zornoza et al., 2013). In this study, the authors believed that the existence of a baffle regulates the flow and increases transverse velocity in the ascending part. By comparing the baffle systems, it was established that the baffle location is one of the important parameters such that, by increasing the baffle distance from the membrane and increasing the ratio of ascending to descending flow, the amount of tension on the membrane surface and the COD removal efficiency decreases (Kia Deliri et al., 2017).

Nitrogen recovery is also one of the important factors in analyzing the function of enzymes in the hydrolysis of food protein, which indicates the ability of an enzyme to separate solution proteins from insoluble types and thus the efficiency of the process during enzyme hydrolysis which is also economically important (Liaset et al., 2002). Piri Gheshlaghi et al. (2016) optimized the nitrogen recovery of hydrolyzed whey protein. In this study, the response surface method was used to optimize the conditions of whey protein hydrolysis process using an alkalase enzyme. The parameters considered in this study were temperature, time and ratio of enzyme to substrate. The results show that the optimal conditions for achieving the highest rate of nitrogen recovery include: a temperature of 47.1 ℃, a time of 173.2 min, and the ratio of enzyme to the substrate of 87.98 units per kg of protein, and in these conditions, the amount of nitrogen recycling was 70.66%.

Lahouel (2016), proposed a new method for converting whey remains into useful organic compounds. In this study, the author used two methods, the first method is a chemical method using 0.5 M of sulfuric acid at 45ºC, and the second method is a biological method using *Bacillus* spp. The results show that whey samples are highly contaminated with organic compounds, the amounts of chemical oxygen demand (COD) and biological oxygen demand (BOD) were 1280 and 703 mg/l, respectively. The results of the study show that chemical treatments using sulfuric acid reduced 93% COD and 95% BOD. Also, the biological method performed with Bacillus for 30 days had less effect on COD reduction (54% compared to 93% in the first method), but both methods are effective in reducing BOD (92% reduction in BOD over 30 days). This work shows that chemical treatment is effective using sulfuric acid, producing effluent properties with the permissible limits set by the standard law. In this study, the organic compounds for the chemical treatment of whey using sulfuric acid contain significant amounts of proteins, peptides, amino acids, and monosaccharides that can be used as energy sources in other processes. This approach can be an appropriate economic method to reduce the environmental effects of cheese affluent.

After several years of concerns about whey and its devastating environmental effects, finally, the United States and Europe banned whey dumping for large cheese companies (Esmithers, 2008); however, some countries still allow discarding whey. This law eventually led to a new approach. The remaining whey is concentrated, filtered and dried and then converted into new products including the whey protein powders and supplements we know today (Agora Vilagas et al., 2012).

2. Solutions to reduce the volume of produced whey

2.1. Whey processing and production of whey powder

One of the problems of whey for use in various industries including fermentation industries is its high volume and its perishability, which increases the cost of transportation. To solve this problem some diary units are equipped to produce whey (Sar et al., 2017; Chandra et al., 2018).

Ghaly and Singh (2006) reported that just over half of the whey produced is in the form of dried whey powder, the industry can hardly retrieve its production costs due to weak markets and high energy costs (Ben Hassan & Ghaly, 1995). With the prevalence of protein powders and supplements industries, whey left over from cheese production should be turned into a very valuable byproduct. This can help policies and laws that prevent whey disposal. The most important products obtained from whey processing are whey powder, whey protein concentrate (WPC), whey protein isolate (WPI) and lactose, (Kotolas et al., 2019). Generally, whey powder contains 8-12% protein and more than 70% lactose, WPC contains 30-89% protein, WPI contains more than 90% protein and it is almost lactose-free (Senmartin et al., 2018). WPI is also used in many food formulations due to its physicochemical and nutritional properties such as the formulation of soup, salad sauce, processed meats, dairy and bakery products, and also in whey-based fermented drinks and whey cheeses (Pereira et al., 2015; Rayan, 2016; Kotolas et al., 2019; Piskors et al., 2019).

Ghanimah (2017) evaluated the use of whey powder in high-fat and non-fat yogurts, the results showed the presence of high protein in such yogurts. In addition, whey powder had the lowest performance of foam and capacity of emulsion. In similar research, Yildiz & Bakirsi (2019) conducted a study in association with the addition of whey powder instead of milk powder in yogurt production. This study showed that the use of whey powder does not change sensory properties.

Amaro et al. (2019) analyzed the prospect of using whey to produce polyhydroxy Alkanovat (PHA). It seems that (PHAs) are real alternatives for common plastics because they are biodegradable and environmentally friendly. Using whey to produce PHA is inexpensive and consistent with environmental sustainability. In this study, current knowledge about the use of produced PHA was presented and new solutions were proposed to overcome the associated challenges with this process.

Kietczewska et al. (2020) have also produced smoothies based on acidic whey with probiotic strains. The main purpose of this study was to determine the potential usages of acidic whey in the production of whey-based drinks containing plant ingredients in equal proportions of acidic whey. In this study, three different drinks were produced and evaluated. The first drink was obtained by adding carrot puree, rose and sea buckthorn, the second drink by adding pear puree and sour cherry juice and the third drink by adding parsley and banana puree. The results showed that drinks that contain whey have a constant color and consistency, but the acidic taste was relatively recognizable. However, all drinks with fruits and vegetables received a very high score in the sensory evaluation. Therefore, as a general conclusion, it can be said that the use of whey and its powder in various research has obtained acceptable results.

2.2. *Concentrating of milk and cheese production*

Dairy industry results in several waste streams and by-products such as whey etc. (Sar et al., 2021). Cheese is actually condensed milk protein after curding and dehydration. Since 1990, research has been conducted on the use of concentrated milk for cheese production (Foster et al., 1990), and ultrafiltration systems have been introduced into dairy industries for this purpose. In this process, the milk is partially or completely condensed to the dry matter of cheese and as a result, after curdling, either less whey is produced than in the case of non-condensed milk, or no whey is produced at all. But what should be taken into account is that during this process, instead of whey, ultrafiltration permeate is created, the volume of which is almost equal to whey in conventional methods, but because of the proteins which do not pass through the ultrafiltration membranes, the amount of organic matter in permeate and consequently its BOD, is reduced, which is environmentally valuable (Katabehei Moradi et al., 2021).

Another method proposed for concentrating of milk from the last decade of the twentieth century is increasing the dry matter of milk to achieve the dry matter of cheese by adding powder components of milk, in which case the cheese can be obtained after curdling, without the need for dehydration process (Hosseinpoor et al., 2014). The difference between this method and ultrafiltration is the complete removal of permeate and the produced cheese is called whey-less or cheese without whey. Up to now, several types of cheese have been produced in this way and their characteristics have been investigated. Nazari (2016) investigated the textural and sensory characteristics of whey-free feta cheese. In this study, produced cheese without whey was considered as an alternative to UF cheese. In this method, the retentate phase used in the ultrafiltration cheese was replaced with a mixture of WPC or MPC cream, then the production process continued with a conventional UF cheese. The results of this study show that treatment containing MPC and WPC in terms of sensory properties has the highest score in general acceptance which shows the improvement of the sensory properties of this cheese as an alternative for UF cheese, but the treatment containing MPC only was less acceptable than the control sample. Due to the similarity of the product properties and the elimination of the filtration system, which results in the reduction of the production cost and environmental pollution, this method can be introduced as a proper alternative to UF cheese,

Sakin-Yilmazer et al. (2014) have reviewed the method of whey-less process in strained yogurt production and different types of cheese. In this research, by adding compounds such as MPC, WPC, caseinate powder and milk powder, milk is concentrated and after pasteurization and homogenization processes and adding starter culture for yogurt and rennet for cheese production, the final product is produced directly from concentrated raw milk.

Lashkari et al. (2020) investigated the optimization of feta cheese production without dehydration by using a mixed statistical design. To achieve optimal conditions for producing feta cheese without whey, MPC, WPC and cream were mixed with ratios of 5-15%, 0-10%, and 45-55%, respectively, with fresh milk at a constant rate of 40%. Cheese samples were produced industrially and finally, the formula was optimized by the response surface method based on the average physicochemical and textural properties of the samples and UF cheeses available in the markets. Optimal values of cream, MPC, and WPC were obtained, respectively, 45.6, 11.7, and 2.7%.

Mirhabibi et al. (2014) formulated a wheyless cream cheese. In this research, wheat fiber (4%), sodium caseinate and skim milk powder (2%) were used in three different formulations based on three different levels of sodium caseinate (2, 4, and 6%) to increase total solid material and also to decrease moisture level, to obtain an expected final texture and at last to reach the possibility to produce wheyless cream cheese. Samples were examined with two control samples in 60 days for chemical, rheological and sensory properties. After some observations on wheyless cream cheese samples and control samples in the preservation period, results revealed the fact that in most of the examinations above, the sample containing 4% sodium caseinates with control samples didn't have a meaningful difference and can be used for producing wheyless cream cheese. Hattem and Hasbo (2015) compared cheese without whey and traditional soft cheese made from buffalo milk. Soft cheese made from the standardized buffalo milk was 4.5% fat and 16% total solid was used as a control, while non-fat milk of buffalo, palm oil and total solid to 30, by adding non-fat milk powder (Treatment 1) and milk protein concentrate (Treatment 2) or 50% non-fat milk powder and 50% milk protein concentrate (Treatment 3) to produce cheese without whey. Results showed that produced cheese by the third method, which contains 50% of milk protein concentrate performed improved chemical properties such as a higher ratio of soluble nitrogen to total nitrogen (SN/TN) and higher non-protein nitrogen to total nitrogen (NPN/TN).

In another study, Salvator et al. (2014) examined the chemical properties of creamy cheese without dehydration. The goal of this study was to investigate the effect of protein concentration of UF permeates on the production of fresh sheep milk ricotta cheese. In this study, significant differences were observed in the characteristics of ricotta cheese depending on protein concentration. It was concluded that the concentration of protein improved the accumulation of heat-induced protein during the thermal curdling process. This led to a better recovery of each protein component in the product, and thus increased the performance of ricotta cheese. Kaminarides (2015) has examined the modified form of Myzithra cheese produced by substituting whey protein concentrate into sheep milk and cream. The properties of ingredients used in the production of mixed Myzithra cheese were: WPC 16.1%, water 49.9%, sheep milk 8%, and sheep cream 26%. The mixture was placed in a polyethylene package for 30 min before being subjected to heat treatment at 90 $^{\circ}$C for 30 min. Myzithra control cheese was also produced in the traditional method. Both samples one day after production and after 25 days of cold storage were analyzed to determine microbiological, physicochemical, rheological and organoleptic properties. Modified Myzithra cheese had higher lactose, potassium and sodium content and less total bacteria count, ash, and calcium content, as well as less hardness and stickiness than control cheese. The results showed that the proposed method can replace the traditional methods.

Gomah et al. (2019) in a study produced soft white cheese without whey separation. This type is a type of cheese in Egypt made from the combination of cow's whole milk and whole milk powder; producing cheese without whey separation was investigated. In this study, different percentages of whole milk powder (0- 5- 10- 15- 20- 25- 30- 35- 40%) were added to cow's milk. The results showed that the cheese performance in the conditions using 40% milk powder had much better performance in terms of taste, cheese slicing, texture and overall score than other samples.

Khiyabanian et al. (2020) also conducted a study on different mixtures of milk protein concentrate and pea protein isolate (PPI) in six combinations with different percentages in making feta

cheese without whey. The results of their research showed that using a high percentage of PPI resulted in a looser protein network, softer structure and shorter shelf-life of cheese. Sensory evaluation of the samples showed that the total score in terms of taste, texture and overall acceptance gradually decreased with increasing PPI levels.

Also, recently, we evaluated the feasibility of wheyless Lighvan cheese using MPC and WPC was investigated. According to physicochemical, rheological and sensory analysis, we achieved the best whey-less Lighvan cheese formulation (*In preparation*).

3. Conclusion

Dairy industry wastes and by-products are defined as the most important environmental pollutants with their lactose, protein and fat contents. In this study, we attempt to provide a complete review of studies conducted in the field of cheese and the environmental problems of whey. As considered in the content of this article, it is clear that the environmental damages of whey must be addressed. Also, in this paper alternative methods such as converting whey into different whey derivatives (WPC, WPI, lactose), and using whey as a nutritious substrate in biotechnology were reviewed. The popularity of Lighvan cheese on the one hand and its workshop scale production on the other hand has made none of the mentioned methods practical to reduce the environmental damages of Lighvan whey, and therefore in this article, the researches related to the production of whey-less cheese has been investigated. As a result, it seems that Lighvan cheese can be produced without whey and the environmental damage of its traditional production can be prevented.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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