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Proposal for taking advantage of whey.

Propuesta para el aprovechamiento industrial del lactosuero.

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ABSTRACT

For every 10 liters of milk, approximately one kilogram of cheese is obtained, and the rest is whey; the whey is rich in proteins, carbohydrates, and minerals and is usually discarded, causing contamination problems due to its high content of organic matter. Whey from a cheese manufacturer in Tlaxcala was ultra-filtered, obtaining a concentrated whey with 7.79 % proteins; the latter was then spray-dried, obtaining concentrated whey powder with 47 % protein; both products comply with the minimum protein indicated in the CXS 289-1995 standard (11 %), so they can be directly marketed or used for reprocessing. The average yield of Oaxaca cheese adding between 5 and 8 % of concentrated whey was 11.33 %, and with no concentrated whey was 11.41 %; in both cases, the consistency of the cheese was similar between them. It was also found that by adding 0.5 % concentrated whey powder to the cheese-making process, the yield increased by 4.16 % compared to the use of 1 % milk powder. By ultra-filtering the whey and drying the resulting fractions, products obtained that can be marketed by the company, in addition to being used in the production of Oaxaca cheese, which implies an economic benefit for the company. In addition to the environmental advantages due to the decrease in contamination due to the disposal of whey.

KEY WORDS: Whey milk, proteins, ultrafiltration, Oaxaca cheese.

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RESUMEN

Por cada 10 litros de leche se obtiene aproximadamente un kilo de queso, el resto es lactosuero; éste último es rico en proteínas, carbohidratos y minerales y usualmente se desecha, ocasionando problemas de contaminación por su alto contenido de materia orgánica. El lactosuero de un fabricante de quesos en Tlaxcala se ultrafiltró, se obtuvo un lactosuero concentrado con 7.79 % de proteínas; este último se secó por aspersión obteniéndose el lactosuero concentrado en polvo con 47 % de proteínas; ambos productos cumplen con el mínimo de proteína indicado en la norma CXS 289-1995 (11 %), por lo que se pueden comercializar directamente o ser utilizado para reprocesamiento. Al agregar máximo 8 % de lactosuero concentrado para la elaboración de queso Oaxaca, se obtuvo un rendimiento promedio de 11.33 %, sin lactosuero el rendimiento fue de 11.46 %; en ambos casos la consistencia del queso obtenido fue similar entre ellos. También se encontró que al agregar 0.5 % de lactosuero concentrado en polvo al proceso de elaboración del queso, el rendimiento subió 4.16 % comparado con el uso de 1 % de leche en polvo. Al ultrafiltrar el lactosuero y secar las fracciones resultantes se obtienen productos que puede comercializar la empresa, además que se pueden emplear en la elaboración de queso Oaxaca, lo que implica un beneficio económico a la empresa. Además de las ventajas ambientales por la disminución en la contaminación por el desechado del lactosuero.

PALABRAS CLAVE: Lactosuero, proteínas, ultrafiltración, queso Oaxaca.

Introduction

Cheese is one of the oldest and most popular foods around the world; it is obtained by milk coagulation using some coagulants such as rennet. There are about 2000 different types of cheese worldwide (García-Muñoz *et al*., 2021), whose characteristics, nutritional, functional, and sensory properties are typical of each one. Overall, they are classified into mature, semi-mature, and fresh cheeses; the most consumed in Mexico are fresh cheeses (Ramírez-López & Vélez-Ruiz, 2012).

During cheese production, approximately one kilogram of cheese is obtained for every 10 liters of milk, and the rest is whey. In the dairy industry, whey has been considered a waste product (Arce-Méndez *et al*., 2016; Asas *et al*., 2021), and therefore, it has been scarcely used and dumped into the environment, with ecological consequences given its high organic load (high content of lactose and proteins that are difficult to biodegrade). As a result, whey is considered the most important pollutant in the dairy industry (Asas *et al*., 2021). Specifically, the Chemical Oxygen Demand (COD) of whey ranges between 50,000 and 80,000 mg/L and the Biochemical Oxygen Demand (BOD) is around 40,000 to 60,000 mg/L (Lappa *et al*., 2019) so its disposal in water treatment plants is expensive.

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The composition of whey depends on its origin and processing, according to the process it has been classified into acid and sweet; the former is obtained by the addition of acid and its average pH is >5; while sweet whey is obtained by the addition of enzymes and its average pH is 5.8-6.6 (Mehra *et al*., 2021). Whey is rich in proteins, fats, lactose, and salts; due to these properties, whey has been used in other industries. Its proteins are very valuable for the pharmaceutical industry, due to their biological, anticancer, antimicrobial, antiviral, antioxidant, osteoporosis retardant, anti-inflammatory, antihypertensive, antithrombotic, and cholesterol-lowering effects (Królczyk *et al*., 2016; Sultan *et al*., 2016; Nabuco *et al*., 2019; Rascon *et al*., 2021). Several studies have shown that enzymatic hydrolysis of whey proteins releases peptides that exhibit biological activity (Tovar *et al*., 2017). In the food industry, there are reports on the benefits of using whey in food processing, such as its contribution to creaminess, texture, water-holding capacity, opacity, and adhesion (Chaturika *et al*., 2015). In addition, whey has excellent nutritional qualities and is easy to digest (Chatterjee *et al*., 2015), so processed whey can be found in the market in powder form or as protein isolate, which is used in formulations of reconstituted milk, protein drinks, in bakery, confectionery, dairy products, meat extenders, and animal feed, among others (Arce-Méndez, *et al*., 2016).

To obtain whey rich in protein and lactose, different treatment technologies have been applied such as microfiltration, ultrafiltration, nanofiltration, and reverse osmosis (Bejarano-Toro *et al*., 2022). Another technique widely used in the food, pharmaceutical, and chemical industries is spray drying, where a liquid product, such as whey, is atomized and a hot gaseous stream is passed through, it can be counterflow, parallel or mixed, which achieves rapid removal of water and the formation of solid particles (Ziaee *et al*., 2019; Rios-Aguirre *et al*., 2021). The contact time is short, and the evaporation of the water allows the material to not significantly increase its temperature, so damage to the material is minimal. In addition, spray drying allows the preservation of products and metabolites of interest, since its reduced water content inhibits bacterial growth (Fabela, 2017). An important application of spray drying is the micro-encapsulation technique, which consists of trapping one substance inside another forming capsules of variable size (from 1 μm to 5000 μm), the coating material is also called wall material. The purpose of the crust material is to protect the compounds inside the core from factors such as humidity, pH, or contact with chemical agents.Wall materials are generally polymers or co-polymers, synthetic or natural, such as starches, maltodextrins, and gums; (Esquivel-González *et al*., 2015). With these techniques, whey can be used and give added value to a product that represents a waste product.

In Tlaxcala, most cheese manufacturing companies discard whey, causing environmental problems due to its inadequate disposal; however, whey has a potential use and is a value-added product for cheese manufacturing industries. This study aimed to reuse the whey produced by a cheese manufacturing company in Tlaxcala, and evaluate its application in the production of Oaxaca cheese; as well as the quality of the concentrated whey for its potential use in the production of other valuable food products.

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Material and Methods

Materials

Milk and whey used were obtained from a cheese manufacturing company located in the municipality of Ixtacuixtla in Tlaxcala, Mexico, whose most commercialized cheeses are panela, Oaxaca, and ranchero. The milk and whey of said three types of cheese were collected from three production lots.

Cheeses were produced in the same company with the inputs that are commonly used; given the confidentiality of the process, these will not be specified. Diagram 1 shows the general scheme of the methodology followed during the research.

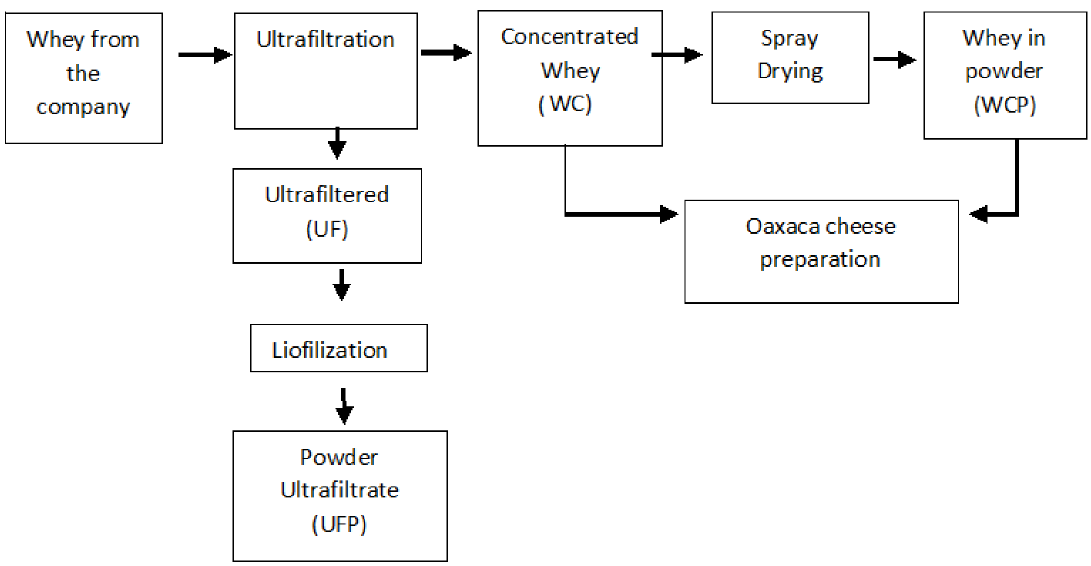

Figure 1. General methodology for whey usage.

Physicochemical characterization

The physicochemical characterization of a) milk, b) company whey, c) ultrafiltration fractions, d) whey resulting from the production of cheese added with whey concentrate (WC), and e) whey powder (WCP), were carried out. The characterization was performed with Milkoscan equipment (S-54B, Foss Electric A/S, Hillerod). The parameters measured were: pH, % fat, % protein, % lactose, % mineral salts, % total solids, and % moisture.

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Ultrafiltration

The whey produced in the company was subjected to an ultrafiltration process in a NIRO Multistage equipment (RO, model R, GEA brand), under the following conditions: membrane cut-off size 10 KDa, inlet pressure 5.5 Kg cm^{-2}, flow rate 9.3 ls^{-1}, temperature 25 - 45 °C. Two fractions were obtained from ultrafiltration, concentrated whey (WC) and ultrafiltrate (UF). The latter was lyophilized at -40°C and a pressure of 0.133 mBar for 12 hours to obtain the ultra-filtrate powder (UFP), the resulting powder was stored at room temperature for later use.

Spray drying

The concentrated whey (WC) was dried in a Galaxi spray dryer (Model 2520), with an inlet air temperature of 200°C, outlet air temperature of 80 °C; evaporation rate of 250 liters h^{-1}, obtaining whey powder (WCP).

Analysis by infrared spectrophotometry FTIR

Whey protein and lactose content were determined by FTIR, comparing the spectra of three whey powders, a) ProWinner, a product marketed as whey protein concentrate without lactose, b) whey donated by the Universidad Iberoamericana campus Puebla (Ibero) and c) Veyco, a commercial food-grade whey; three commercial milk powders, Nido®, Novamil®, and Nan II®, and the whey obtained in this work. Calibration curves were prepared with bovine albumin and lactose from Sigma-Aldrich, and absorbance was determined at wavelengths of 1800-800 cm^{-1}, using a Bruker FTIR equipment model Vertex 70 with ATR, using an integration time of 300 seconds.

Production of Oaxaca cheese

The cheese was made following the process established by the company (respecting the confidentiality of the process) wherein the different amounts of WC (0, 5, 8, 10, 12, 15, and 20 % volume/volume), and WCP (0, 0.25 and 0.5 % weight/weight) were used, based on the volume of milk used. WC or WCP, as appropriate, were mixed with milk to complete 4 liters. Afterward, rennet was added and kept at 35 °C for 2 h until the coagulate was formed, which was separated manually, then placed in a container with water at 80 °C for 2 minutes, after which it was manually stretched to form strands, which is the main characteristic of Oaxaca cheese. The ease of processing was qualitatively observed as well as the elasticity of the cheeses, which were then weighed to obtain the yield per liter of milk used.

Statistical analysis

The statistical analysis of the results was carried out through a one-way analysis of variance (ANOVA) and then an analysis of mean comparisons using the Tukey-Kramer test was applied, with a significance level of 0.05.

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Results and Discussion

Physicochemical analysis of milk and whey from the company

Initially, the physicochemical characteristics of the milk and whey obtained after the production of panela, Oaxaca, and ranchero cheeses in the cheese manufacturing company were evaluated (Table 1). It is observed that the composition of the three whey was very similar; the pH of the ranchero cheese whey was more acidic, and in acid whey, a lower amount of lactose and protein has been reported, which corresponds to the results obtained (Chandrapala *et al*., 2015). The whey of Oaxaca cheese contained a higher amount of lipids (0.29 %), and higher than reported in other research (Bejarano-Toro *et al*., 2022). It has been reported that 30 % of milk lipids are unsaturated fatty acids, this group of acids deserves special attention due to its health benefits, in the cardiovascular system, immune function, in addition to anticancer properties among others (Pereira, 2014). The whey of panela cheese had higher solids content (7.57 %) and higher than data reported in other research (Iltchenco *et al*., 2018). When comparing the composition of milk with whey composition, it is observed that milk had between 2.4 and 2.8 times more protein than whey, and between 11 and 36 times more lipids, and thus higher total solids content. This is explained by the fact that during cheese making, the fat and protein portions are coagulated to produce cheese; however, between 36 and 40 % of the proteins remained in the whey; almost all of the lactose, as well as part of the minerals. In other words, a residue rich in nutrients remains that can be used either for cheese production itself or in the food and pharmaceutical industries, since its biological value (the extent to which nutrients are absorbed and utilized by the body) is even greater than that of the egg (Arce-Méndez *et al*., 2016).

On the other hand, the results in Table 1 agree with what has been reported by other authors (Iltchenco *et al*., 2018; Bejarano-Toro *et al*., 2022), who reported that whey contains 0.8 to 1.0 % protein, 4.5-4.65 % lactose, 0.5 % minerals, 0.5 % fat, 6.98 % total solids, 0.6-0.7 % mineral salts, and a pH of 6.49-6.52.

Obtaining whey concentrate (WC), ultra-filtrate (UF), and whey powder concentrate (WCP)

Given that proteins are thermolabile, it is not advisable to subject whey to operations involving heating for concentration, since proteins may denature. Therefore, whey concentration was performed by ultrafiltration since it is a mechanical separation by molecular weight, so the damage to the proteins is minimal (Solís *et al*., 2017). As a result of the ultrafiltration process, two fractions were obtained the retained (WC) and permeate (UF), whose protein content was 7.79 % and 1.15 % respectively (Table 2). Results are higher than previous reports of concentrated whey derived by ultrafiltration, where the protein was quantified at 5.22 % and pH of 5.79 for the retentate and 0.21 % protein and pH of 5.78 for the permeate (Kukucka & Kukucka, 2012; Proaño *et al*., 2021).

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Table 1. Physicochemical analysis of milk and whey obtained in the cheese manufacturing company.

Property	Milk	Panela cheese whey	Oaxaca cheese whey	Ranchero cheese whey
pH	6.42 ± 0.17[a]	6.36 ± 0.15[a]	6.30 ± 0.12[a]	5.41 ± 0.12[b]
Lipids (%)	3.25 ± 0.27[a]	0.11 ± 0.02[b]	0.29 ± 0.06[a]	0.09 ± 0.1[b]
Protein (%)	3.12 ± 0.14[a]	1.26 ± 0.12[b]	1.25 ± 0.23[b]	1.12 ± 0.17[b]
Lactose (%)	4.46 ± 0.35[a]	4.28 ± 0.39[a]	4.28 ± 0.25[a]	4.04 ± 0.31[a]
Mineral salts (%)	0.88 ± 0.05[a]	0.72 ± 0.09[c]	0.75 ± 0.1[c]	0.78 ± 0.04[b]
Total solids (%)	11.51 ± 0.36	7.57 ± 0.27	6.76 ± 0.25	6.43 ± 0.23
Humidity (%)	88.49 ± 0.43[a]	92.43 ± 0.57[a]	93.24 ± 0.45[a]	93.57 ± 0.63[a]

Equal letters in a line indicate that there is no statistical difference ($\alpha < 0.05$).

Table 2. Physicochemical analysis of concentrated whey and specifications of the CXS 289-1995 standard.

Property	WC	UF	WCP	Norm CXS 289-1995
pH	6 + 0.44[b]	5.89 + 0.52[b]	7.97 + 0.69[a]	>6
Protein (%)	7.79 + 0.72[b]	1.15 + 0.09[c]	47.32 + 1.1[a]	Min 11%
Lactosa (%)	2.09 + 0.32[a]	0.26 + 0.08[b]	1.58 + 0.79[a]	Max 2%
Lipids (%)	52.5 + 0.98[a]	45 + 0.44[b]	39.85 + 3.56[b]	Max 61%
Humidity (%)	83.75 + 0.93[b]	93.36 + 0.39[a]	5.14 + 0.78[c]	Max 5%
Total solids (%)	16.25 + 1.02[b]	6.4 + 0.39[c]	94.86 + 0.82[a]	Unspecified

Equal letters in a line mean that there is no statistical difference (α <0.05).

Using a 10 kDa ultrafiltration membrane it was possible to concentrate proteins, hence the increase observed in that parameter in the concentrated whey (WC), as well as an increase in total solids compared to the permeate (UF). This can be explained since between 70 and 80 % of the total proteins are α-lactoglobulin and β-lactoglobulin, whose molecular weight is 14.2 and 18.3 kDa respectively; the rest of the proteins are serum albumins whose molecular weight is 69 kDa (Kukucka & Kukucka, 2012). In the case of lactose, its molecular weight is 342 g mol^{-1}, so theoretically it should not be found in the concentrate; however, Table 2 and Figure 1a show that lactose was present in WC and WCP; this can be explained by the components of serum which are deposited on the surface of ultrafiltration membrane, making difficult the penetration of low molecular weight molecules such as lactose; in addition, Tarapata *et al.* (2022) reported that some physicochemical properties such as increased ionic strength and calcium content in the lacto-serum facilitate membrane fouling.

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According to Table 2, the parameters measured for WCP comply with quality requirements established in the CXS 289-1995 Standard, except for water content, which was slightly higher than the Standard, so it is suggested that the drying time be increased. It is important to note that for food grade whey it is specified that the protein content must be a minimum of 11 %; the WCP obtained has a protein content of 47 %, 4 times higher than the minimum specified; therefore, the product that can be obtained with the company's whey, after ultrafiltration and spray drying, would have a higher sales value due to its higher protein content. The result obtained is higher than that reported by Bejarano-Toro *et al*. (2022) who obtained 45 % protein from whey when subjected to the ultrafiltration process with a 10 kDa membrane.

Protein and lactose content of whey WC, WCP, and UFP

In the cheese production company, when milk supply decreases, they use 1 % of powdered milk for the formulation of their products; therefore, once the concentrated whey was obtained, it was dried to obtain powdered whey and determine the use of both concentrated whey (WC) and powdered whey (WCP) for cheese production and reduce the use of powdered milk. A spray dryer was chosen for the dehydration of WC since the use of this equipment has several advantages: it ensures uniformity in the particle size of the product (uniform granule size is a very important quality parameter); the high drying speed minimizes contact time with the hot air, this prevents protein denaturing, improving the quality of the product and thus its competitiveness in market (Sosnik & Seremeta, 2015). The characteristics of the WCP thus obtained are shown in Table 2, and were compared with Standard CXS 289-1995, which establishes the specifications for food-grade whey powder.

Additionally, the protein and lactose content of WCP was compared with that of the commercially available whey powders Ibero, Veyco, and ProWinner 100 % whey, the latter being a popular consumption product among athletes; a such comparison was carried out by FTIR spectroscopy analysis. IR spectroscopy is a non-destructive technique that requires practically no sample preparation, in addition to its sensitivity and selectivity, it has become a tool of choice for qualitative and quantitative analysis in the dairy industry, replacing methods such as Kjeldahl (Pereira *et al*., 2020). In the present analysis, only regions of the spectrum where the characteristic signals of proteins and lactose are found were considered, since these are the whey compounds of greatest economic and nutritional interest. The characteristic signals of lactose functional groups are recorded in the region of 900-1300 cm^{-1}, and the bands corresponding to protein amide I groups are between 1500-1400 cm^{-1}, amide II between 1300-1400 cm^{-1} protein-lipid interactions from 1600-1700 cm^{-1} and lipid from 1700 to 1800 cm^{-1} (Solis-Oba *et al*., 2011; Pereira *et al*., 2020; Hong *et al*., 2021).

In the IR spectrum (Figure 1a) it is observed that the area of the signals corresponding to proteins was substantially larger for WCP than those of the Ibero and Veyco powdered whey powders, indicating a higher protein content in WCP (47 %); in the same spectrum, lactose content was much lower in WCP than in the other two products. This shows that WCP is a product with a higher protein content with a low lactose concentration, characteristics that make it more attractive, nutritionally and economically than the Ibero and Veyco lactose products, which contain

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12 % protein. As for ProWinner, Figure 1a shows that the protein content is higher in ProWinner (79 %), while the lactose content is higher in WCP.

Table 3 shows a comparison of the protein content of various highly commercial whey powders, as well as the price to consumers; from this comparison, it can be observed that the commercial value of whey powder is very attractive, especially considering that it is a by-product that is usually considered a waste product; in addition, obtaining whey is relatively simple since the ultrafiltration and spray-drying processes recover a high proportion of the milk proteins that did not remain in the cheese, with low lactose content. Therefore, if the company invests a little more in research and development, it will be able to have a product with a higher amount of protein and without lactose, it will have extra profits from the commercialization of WCP, after its characterization to evaluate its stability, swelling capacity, solubility, size distribution, Z potential, etc.

Likewise, WCP was compared with the commercial milk powders Nido®, Novamil®, and Nan II®. Figure 1b shows the corresponding FTIR spectra. Figure 1b shows that WCP has a higher protein content with respect to commercial kinds of milk, so WCP obtained can be used in the company since a product of higher nutritional quality than some commercial milk powders are obtained. The lactose content of WCP was the same as Nido® and Novamil® milk; the highest amount of lactose was recorded in Nan II® milk. Lactose is a disaccharide found in milk and is the most important carbohydrate in infant nutrition (Vandenplas, 2015).

From the above it can be seen that another possible use of whey is the sale of WCP to companies that manufacture milk formulas; these products are made with protein, lactose, and minerals from cow's milk, vegetable oils, and vitamins. As shown in Table 3, the potential profits for the company are very attractive for promoting its product in other areas of the dairy industry.

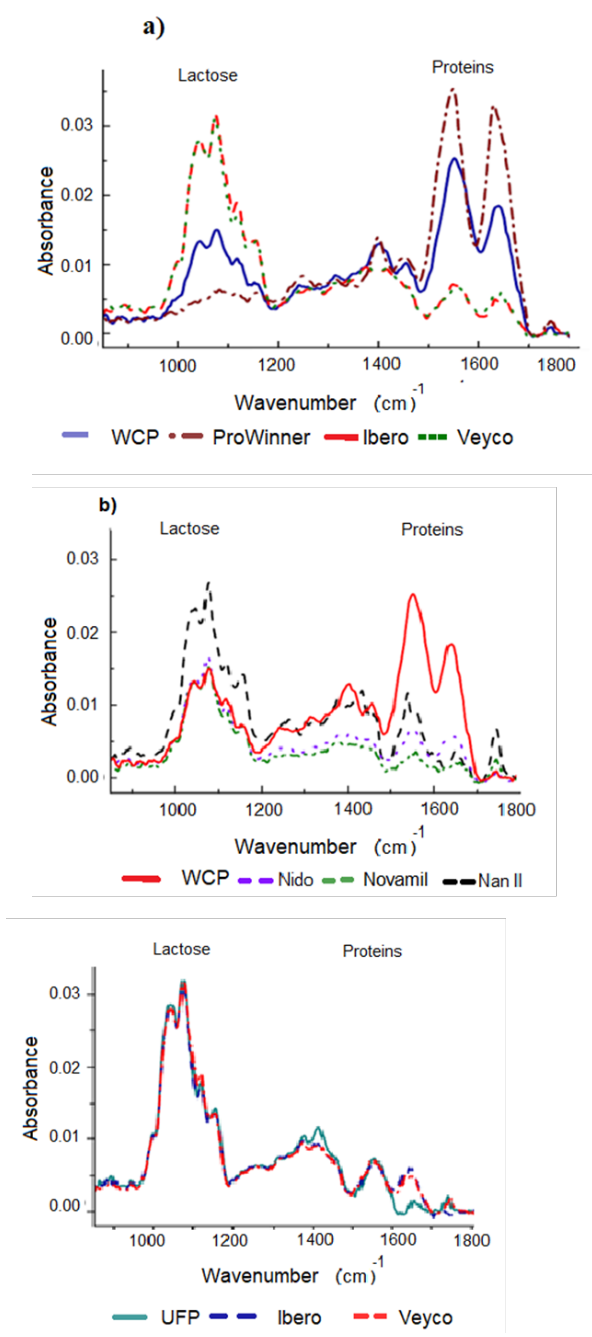

Figure 1. a) FTIR spectra of WCP, ProWinner®, Ibero®, and Veyco® whey; b) FTIR spectra of WCP and powdered kinds of milk Nido®, Rabins®, and Nan II®; c) FTIR spectra of UFP, ProWinner®, Ibero®, and Veyco® whey

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Table 3. Comparison between whey and milk powders with the WCP.

Product	Protein (%)	Price*	$ /g protein
WCP	47.32	----	------
ProWinner	72.5	$1700/2000g	$0.85
Evolution WP 100	80	$1128/1400 g	$0.80
Forza Whey Pro	75.7	$1375/2270g	$0.61
Nan II	10	$361/1200g	
Nido	9	$123/720g	

*Prices consulted on Amazon Mexico, September 2022.

Generally, protein powder concentrate is used in greater proportion, since it contains a higher protein content than the filtrate, but the latter could also be exploited in the dairy industry. UF was freeze-dried (UFP) to determine if it can also be used in the dairy industry, its FTIR spectrum was compared with that of Veyco® and Ibero® whey powders, these spectra are shown in Figure 1c. It is observed that the UFP spectrum is practically the same as the other powdered whey powders, and if it is compared with the protein and lactose content of tested milks in Figure 1b, it can be seen that they are similar to each other. This indicates that both fractions obtained from the ultrafiltration of whey can be exploited, obtaining two products, WCP which is a product rich in protein (47 %), and UFP with a protein content of 12 %, both products exceed the minimum requirement of 11 % protein established in the CXS 289-1995 standard.

In 2018, the price in Europe for milk powder was $3018/ton and for whey powder $802/ton (https://www.canilec.org.mx/estadisticas%20lacteos%202019.pdf) According to this information, the company could obtain extra income by marketing both products (WCP and UFP).

Formulation of Oaxaca cheese with the addition of WC or WCP

According to the obtained results, the most immediate use that the company can make of whey is to integrate it into the same cheese production; the use of both liquid whey concentrate (WC), and whey powder (WCP) was evaluated, the latter to determine if it is possible that the use of powdered milk, which is occasionally used in the company when the milk supply is low, can be substituted by whey powder. Several preparations were made with different amounts of both WC and WCP whey.

Table 4 shows the yield obtained when making Oaxaca-type cheese with different amounts of WC, as well as the consistency and ease of processing. It was found that the cheese yield obtained using WC was lower than the yield obtained without using WC (0 %), and decreased as the amount of WC increased. Cheese obtained using 5 and 8 % WC showed good consistency (elasticity) and good processability. However, when increasing the amount of WC above 8 %, the product obtained was creamy and did not allow the formation of strands, which is the main characteristic of Oaxaca cheese. It is important to mention that whey has a lower amount of protein and fat than milk; in this sense, proteins are responsible for the spatial alignment of the cheese strands, and when the amount of protein decreases, it makes cheese stringing difficult. In addition, it has been reported that fat also helps in the spinning, it is distributed following the orientation of the protein fibers, so if the amount of these fats decreases, the spinning is deficient (Ramírez-

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López & Vélez-Ruiz, 2012). Whey has 55 % less fat content than milk, when formulations are made by increasing the percentage of whey, the amount of lipids in the mass is reduced, thus changing the consistency and it is not possible to make the characteristic yarn of Oaxaca-type cheese. This explains why by increasing the amount of WC added, a lower cheese yield was obtained and its processing was poor; however, statistically, the same yield was obtained by adding up to 12 % WC; but it is recommended to use a maximum of 8 % since it is the maximum amount evaluated that allows obtaining a good elastic consistency.

Table 4. The yield of Oaxaca cheese was prepared using WC.

WC (%)	Cheese (g)	Yield (%) (Cheese/milk)	Consistency	Cheese processing
0	458.5[a]	11.46[a]	Elastic	Good
5	428[ab]	11.26[a]	Elastic	Good
8	420[ab]	11.41[a]	Elastic	Good
10	398.5[b]	11.07[ab]	Creamy	Regular
12	393.5[b]	11.18[ab]	Creamy	Regular
15	359.5[bc]	10.57[b]	Very Creamy	Bad
20	326[c]	10.19[b]	Very Creamy	Bad

Equal letters in the columns mean that there is no significant difference ($\alpha < 0.05$).

The use of WCP to formulate Oaxaca cheese was also evaluated and compared to a formulation using 1 % of the milk powder used in the company, the results are shown in Table 5.

It was observed that using WCP the cheese processing and consistency was the same as using powdered milk, but the cheese yield was 4.1 % higher using 0.5 % WCP compared to using 1 % powdered milk, probably because WCP has a higher protein content compared with powdered milk. Using 0.25 % WCP gave the same yield as using 1 % milk powder, with no statistical difference between them.

Table 5. The yield of Oaxaca cheese was prepared using WCP and milk powder

Powder milk (%)	WCP (%)	Cheese (g)	Yield (%) (Cheese/milk)
1	0	480[b]	12.0[b]
0	0.25	492[ab]	12.3[ab]
0	0.5	501[a]	12.5[a]

Equal letters in the columns mean that there is no significant difference ($\alpha < 0.05$).

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In the production of Oaxaca cheese with 0.25 or 0.5 % WCP, the company would have the following advantages: a) the product has good incorporation of whey components (fat, proteins, lactose, minerals), b) it allowed good processing from the point of view of strand formation, elasticity, and texture, c) there was an increase in yield, which on a large scale translates into higher profits and d) they can have economic savings by reducing the purchase of powdered milk. Depending on the time of year, the supply and demand of milk, as well as prices, depend on the time of year, for example, in times of drought or winter, milk production is low and prices rise. The results obtained indicate that the whey powder can be used for the production of Oaxaca cheese when the milk supply is low or milk prices are high.

Physicochemical analysis of the whey resulting from the cheese obtained by adding WC or WCP.

According to the results obtained, it is recommended that the company use 8 % whey concentrate (WC) and 0.5 % whey powder (WCP), since with these amounts the yield, processing, and appearance are similar to those obtained using only milk. To determine if whey obtained from these formulations can continue to be used in subsequent production cycles, the whey obtained after the production of Oaxaca cheese with the addition of 8 % WC or 0.5 % WCP was analyzed, and its physicochemical properties are shown in Table 6. This indicates that it would be important to carry out the production of Oaxaca cheese by reusing the resulting whey and analyzing the characteristics of the resulting cheese to determine if whey can be recycled. This possibility would offer the company another opportunity to economize and increase its profits in terms of cheese production.

Table 6. Analysis of the whey resulting from the cheese production using 8 % WC and 0.5 % WCP.

Parameter	Cheese whey obtained with 8% WC	Cheese whey obtained with 0.5% WCP	Cheese whey obtained with pure milk
pH	5.89 ± 0.35^{ab}	5.57 ± 0.26^{b}	6.30 ± 0.22^{a}
Lipids (%)	0.25 ± 0.07^{c}	0.37 ± 0.09^{a}	0.29 ± 0.06^{b}
Proteins (%)	1.44 ± 0.06^{b}	1.78 ± 0.12^{a}	1.25 ± 0.23^{b}
Lactose (%)	4.53 ± 0.62^{a}	4.55 ± 0.45^{a}	4.48 ± 0.55^{a}
Mineral salts (%)	0.76 ± 0.04^{a}	0.77 ± 0.06^{a}	0.75 ± 0.1^{a}
Total solids (%)	6.98 ± 0.69^{a}	7.47 ± 0.58^{a}	6.76 ± 0.65^{a}
Humidity (%)	93.02 ± 0.91^{a}	92.53 ± 0.61^{a}	93.24 ± 0.85^{a}

Average of three measurements, + standard deviation

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Conclusions

Whey, being a by-product rich in protein, lactose, and other nutritional components, can be used, thus avoiding being discarded and affecting the environment. In Tlaxcala state, most of the cheese manufacturing companies discard their whey, and due to its high organic load, its treatment in the state's water treatment plants is complicated and expensive. Through ultrafiltration and spray drying, a whey concentrate (WC) and a whey powder (WCP) with 7.76 and 47 % protein, respectively, were obtained; both products were shown to be suitable for cheese production. The use of whey will bring economic advantages to the company, since during cheese production it can reduce the use of liquid milk by substituting it with the use of 8 % WC or reducing the requirement of powdered milk by using 0.5 % WCP, without detriment to cheese yield. In addition, after further analysis, the obtained whey could be marketed, since it has an attractive market in different industries.

Authors contribution

"Conceptualization of the work, ASO, MMSO; methodology development and experimental validation, OTG; analysis of results, ASO, MMSO, RMMC; data management, RMMC; manuscript writing and preparation, MMSO; drafting, revising and editing, AASO; project manager and fund acquisition, MMSO.

All authors of this manuscript have read and accepted the published version of the manuscript."

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Conflict of interest

The authors declare that they have no conflict of interest.

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