Stochastic Optimization of Dairy Supply Chain Valorization Model by Considering Byproducts

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Abstract

The paper deals with the dairy valorization problem. A new stochastic model for optimizing dairy valorization model is proposed. It takes into account the multipurpose and batch characteristics of dairies and employs the time resource distribution over the processing nodes and products. The dairy valorization model developed and analyzed in three scenarios. The first one refer to the definitive space, which indicates the lack of demand dependence on various factors and in the second as well as the third scenarios denote eliminate the space of certainty and it is to consider the quantity demanded of the products, quantity and quality of the incoming raw material (Raw Milk), respectively. Iran's Kurdistan dairy supply chain is used as a case study. The results of the analysis will be presented in two ways, considering and non-considering of byproducts. The results reflect improved supply chain profit in case of using byproducts instead of discarding them. The model shows that, by utilizing any byproducts, while increasing supply chain profit, the amount of nutrient loss decreases. By entering space of certainty into an uncertainty, the chain's profit reduces, which indicating the importance of acting to reduce demand fluctuations in order to improve the overall supply chain profit.

Keywords
Valorization, Stochastic Optimization, Dairy supply Chain, Byproduct, Food Waste, Iran's Kurdistan Dairy Supply Chain

1. Introduction

Dairy industry had been found its position all over the world. Increasing importance of dairy products lifts their market demand and affects the processing sector. Supply chain (SC) models, appears as a useful tool for efficient analysis of the environmental impact in dairy products and their portfolio optimization. There are three main actors which have the following goals in dairy supply chain: 1) dairy processors – looking for maximum profit; 2) markets – pursuing customers' demand satisfactions; and 3) milk collection centers – aiming to sell most of the collected milk. It is very important to have a clear picture of the tradeoff margin existing between these three actors (Vaklieva-Bancheva *et al.,* 2007).

The main difference of dairy supply chain with others is its perishable products, which it influences the whole supply chain, from getting milk at dairy plants till delivery end dairy products to consumers. In dairy supply chain the time factor has a very important role such as seasonality factor, thus each factor that influences it, is more significant and effective factor in studies. In the case of seasonality, affect qualitative and quantitative features of

incoming raw material of dairy supply chain. Fig. 1 shows main issues which can be participate in dairy supply chain studies.

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                    │  Dairy supply chain management  │
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| Supply chain coordination | Demand and supply prediction (Predictive modeling) | | Transportation systems | Location |

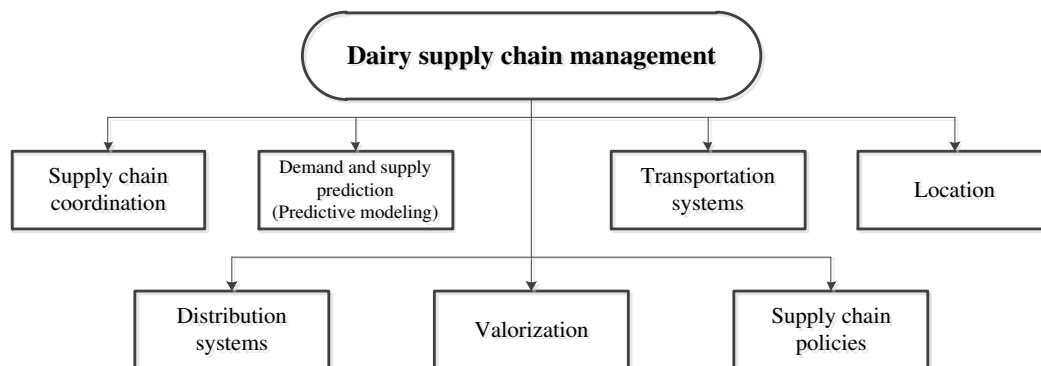| | Distribution systems | Valorization | Supply chain policies |

Figure 1 - Main issues in dairy supply chain management

Dairy supply chain structure contain farm animal breeding and cattle, milk collection centers, dairies products and finally all other components of distribution systems which include retailers and wholesalers. We need to have a proper policy in order to use its potential. In the other side, due to high perishability, food waste rises. To reduce food waste, there are some solutions like valorization. By valorization and recycle byproducts (BP), it can be prevented from uncontrolled and indiscriminate dairy food waste. Valorization model is used to enhance or try to enhance the price, value, or status by organized and usually governmental action. One of the tools uses in the dairy frameworks is dairy valorization model (DVM). DVM has used to identify the best and the most economical composition of the dairy products. Valorization tools are used in various fields of food supply chains such as, energy, main products, byproducts and other important sectors of this kind of supply chains.

In this paper, we focus on the role of byproducts in the dairy supply chain valorization model and its position in supply chain optimization. By developing the existing models and considering important factors such as price changes and seasonality of raw milk characteristics, we examine the conditions of uncertainty in demand in the model. By implementing this model on the case study, the effects of byproducts and the demand uncertainty with respect to the two above-mentioned factors will be examined.

In the following sections, we show literature review of dairy valorization studies, after that present a new stochastic model to show the position of byproducts in dairy processing and analyze it in the case study. Iran's Kurdistan dairy supply chain has been chosen for analyze the presented model.

2. Literature review

Effective dairy supply chain management due to its complexity requires integrated tools. In a dairy supply chain, the main incoming raw material is raw milk (RM) which collected from dairy farms and industrial dairy centers. RM is used for the production of all dairy products. Since the nutrient content of RM changes during the year so the volume and type of end products (EP) also change. During EP production, some other nutrient produce in an unplanned way. This nutrient is called byproducts (BP) which can be used in other part of process. To effective management of whole dairy chain a comprehensive model that considers all internal and external factors, is required.

The literature contains numerous approaches that maximize profit of dairy supply chains. Table 1 shows some of the most important studies. These kind of researches start with a general analysis of dairy manufacturing processes (Roupas, 2008), through allocation models that capture parts of the production process allocation models (Kerrigan et al., 1986) which aim to allocate milk to all dairy products (Mellalieu et al., 1983; Benseman, 1986), and some other models which show whole dairy supply chains (Ahumada et al., 2009; Banaszewska et al., 2013; Roupas, 2008). Ahumada and Villalobos (2009) showed a framework for DVM, after that Banaszewska et al., (2013) extended previous model with more features and presented a more comprehensive model. There are some other researches which consider food supply chain modeling and optimization (Halil and et al., 2017; Musavi & Bozorgi-Amiri, 2017; Miranda-Ackerman et al., 2017).

Table 1- Dairy supply chain studies

Ref.	Key and main words								Modeling approaches			Solution approaches	
	substitution issues in dairy industry	Inventory	Contracts	Predictive models	Valorization	Transportation Cost	VRP	Uncertainty	Linear programming	Multi objective optimization	Non-Linear programming	Heuristic& Meta heuristic & Fuzzy approaches	Exact approaches
Yates & Rehman (1997)	✓								✓				
Strande´n & Lidauer (2001)	✓	✓									✓	✓	
Bancheva et al., (2007)		✓								✓	✓		
Hovelaque et al., (2008)		✓	✓								✓		✓
Roupas (2008)				✓							✓	✓	
Guan & Philpott (2009)		✓									✓		
Zarei et al., (2010)		✓									✓	✓	
Vellinga et al., (2011)		✓									✓		
Yu & Nagurney (2012)	✓	✓									✓	✓	

Table 1- Dairy supply chain studies (Continued)

Ref.	Key and main words								Modeling approaches			Solution approaches	
	substitution issues in dairy industry	Inventory	Contracts	Predictive models	Valorization	Transportation Cost	VRP	Uncertainty	Linear programming	Multi objective optimization	Non-Linear programming	Heuristic& Meta heuristic & Fuzzy approaches	Exact approaches
Doole et al (2012)		✓			✓						✓		
Validi et al., (2014)		✓								✓	✓	✓	
Sustainable product (2014)		✓									✓	✓	
Pinior et al., (2015)		✓										✓	
Sadeghi et al., (2014)		✓				✓					✓	✓	
Sethanan &Pitakaso (2015)							✓				✓	✓	
Perrot et al., (2015)		✓									✓	✓	
Gold et al., (2012)		✓						✓			✓	✓	
Bello et al., (2012)		✓									✓	✓	
Duan & Liao (2013)		✓						✓			✓	✓	
Bourlakis et al., (2013)		✓									✓	✓	

In the following, studies conducted in the valorization and also factors involved in these models which can be seen in Fig. 2, are briefly explained. Even though the dairy production problem has been treated in many ways, a comprehensive model that considers main and important factors which integrated in a unified framework not yet available in the literature.

Figure 2. Dairy products valorization factors

Some factors that involve in the DVM have introduced, these characteristics are: modeling technique; modeling approach (deterministic or stochastic); planning horizon (single period, short term, mid-term, or long-term); recipes based on milk composition; seasonality of RM composition and RM supply included; part of product portfolio covered—whole product portfolio or a particular product group; BP reutilization; BP transport; RM transport ; network of supply regions and production locations; changes in product prices—throughout the whole planning horizon, within planning periods that determine the complete planning horizon, and no changes included ; model tested on a real-life case—application (Banaszewska et al., 2013). One of the most important applications of DVM is valorization of raw milk which is affected by many restrictions. Some of these restrictions can be pointed to the seasonality of milk composition, the milk collected, the interdependence of the production process, the amount and type of demand and supply, current capacities and transport streams. The contrast between the restrictions and understanding of the production process can make valorization models more comprehensive and high functional. Among the above mentioned restrictions, seasonality is the most effective and important factor that influence DVM. Fluctuations in demand and prices of dairy products, intense competition and increased access to foreign markets and the rules that significantly restrict performance are affected dairy processes. Due to the complexity of dairy supply chain that results from its special features, need to advanced methods for the efficient dairy supply chain management.

In dairy supply chain, raw milk is collected from farms and collecting center and used for producing dairy products. Amount and type of EP depends on the nutrients in RM that is variable during the year. Also, dairy production processes are undependable, byproducts that are produced in one section, can be used in another section of processing. In order to manage the productivity of milk collected, effective logistical infrastructures are required. A comprehensive model which could cover whole production process including internal and external factors should be designed. This model can be showed as a DVM. Such a model depicts directly and indirectly the main factors affecting milk allocation process.

The literature shows various approaches to optimize different objective functions which start with Roupas research at 2008 and after that continue with other researches (Kerrigan et al., 1986; Papadatos et al., 2002; Burke, 2006; Doganis et al., 2007), allocation models that aim to allocate milk to all dairy products (Benseman, 1986; Wouda et al., 2002) and models that represent whole dairy supply chains (Guan et al., 2011; Vaklieva-Bancheva et al., 2007).

The production problem of dairy products has been studied in different ways, but an integrated model which includes most of the main factors necessary to provide a large map of the production process of these products is not found. As can be seen in table 2, a research covering all factors affecting the valorization of milk in dairy supply chain has not examined (Banaszewska et al., 2013). Benseman's model (1986) considered the seasonality feature of milk components but not possibility of selling and purchasing RM. In this model volumes of EP obtained from one ton of RM depend on the composition of milk; however, volumes of BP are fixed, notice that, this assumption is not true in reality because milk composition affects both EP and BP volumes. Additionally, there isn't clear relation between EP and BP, it's impossible to use multiple production recipes. Other researches which considers more relevant factors are Mellalieu and Hall (1983), Vaklieva-Bancheva et al., (2007), and Guan and Philpott (2011). In Mellalieu and Hall model (1983), a part of the dairy portfolio was considered but it wasn't obvious which part of portfolio exactly. In this paper the transportation of RM was used but other transportation were not considered. The BP issues such as the possibility of using them in other part of process wasn't considered. In Vaklieva-Bancheva et al. model (2007) existing compromise between SC's members were evaluated. The number of products which considered in this research were limited so the relation between end products and byproducts wasn't clearly showed. Similar to the previous researches, the possibility of using BP and their transportation were not clearly considered. The model developed by Guan and Philpott (2011). The model developed by Guan and Philpott (2011) considered uncertainty in milk supply which its demand depends on price. Byproduct issue was not considered and didn't consider developing dairy portfolio. The seasonality of milk was considered only via volumes supplied throughout the year, whereas considering seasonality of milk would advance supply chain management (Geary et al., 2010).

In the next section, we introduce a new valorization model which contains byproduct issue beside other important factors, after that in the analyzing section we consider seasonality which affects quality and quantity of raw milk and price variation effects. Iran's Kurdistan dairy supply chain helps us to show the effects of these factors on dairy supply chain's profit function.

3. Supply chain Model

We develop a model which considers the set of I milk processing centers (plants). Each one comprises the similar types of production units, having different volumes or rates. The same range of P products must be processed in the plants within the horizon H. Production costs per a unit of product are different for dairies but constant over the time. Milk is the main raw material used in manufacturing that is taken into account. We suppose that S distribution centers supply plants with the whole milk. Products sell on M markets. The distances between milk centers, plants and markets are known. Transportation costs depend on the capacity of vehicles used. Transportation costs, products and milk costs are also constant over the planning horizon. Market demands and milk provisions from distribution centers are fixed for the horizon. Applying the supply chain policy, the goal is to develop a deterministic mathematical model for optimal short-term planning of the dairy production complex so as to result in the optimal products portfolio for the total site. Concerning the supply chain that must be designed, we assume that its structure is a constant over the horizon-H, but unknown. Also we accept that no stocks and milk accumulations are permitted in the plants (Fig. 3)

The definitions of parameters related to the suggested model are as follows: (IRR: Iranian Value)

Parameters:

$C1_{m,p}$- Cost price of product **p** in market **m**th [IRR];

$C2_{i,p}$- Production cost of product **p** and Byproduct **b** in plant **i**th [IRR];

$C3_s$ - Cost of milk in the distribution center **s**th [IRR];

$C4_{i,s}$- Transportation cost from the center **s**th to plant **i**th [IRR per ton/ km];

$C5_{i,m}$ - Transportation cost between plant **i**th and market **m**th [IRR per ton/ km];

$L1_{i,s}$ - Distance between plant **i**th and distribution center **s**th [km];

$L2_{i,m}$ - Distance between plant **i**th and market **m**th [km];

M_s - Capacity of the milk distribution center *s* for the horizon H, [tons];

Following additional data, needed for portfolio feasibility constraints definition and also average products yield, must be given:

N- Number of unit types involved in plants **i**th;

$U_{i,n}$- Summarized capacity of unit's type **n** in plants **i**th, [m^3];

$SF_{p,n}$- Size factor of product- on equipment type **n**, [m^3/ton];

$T_{p,n}$- Processing time of product **p** in equipment type **n**, [hour];

YF_p - Average yield of product **p** from a unit mass of milk, [ton product/ton milk];

$Fraction_{i,p}$- The fraction of that BP **b** obtained while producing 1 ton of the desired product **p** in palnt i_{th};

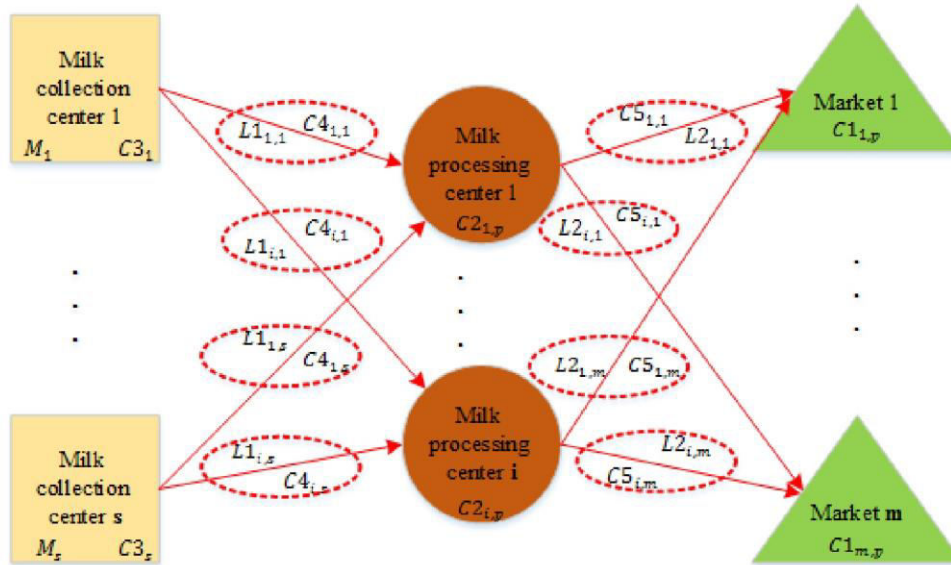$D_{m,p}$- The market demand for product **p** in market m_{th};

Figure 3. Supply chain model and parameters

Decision Variables:
To describe the problem the following variables are as decision variables:
Binary variables are used to structure the supply chain. Two sets of binary variables are set up as following:
Variables χ - to structure the SC between the plants and markets:

$$\chi_{i,p,m} = \begin{cases} 1 & \text{If Plant i is connected with market } \mathbf{m} \\ 0 & O.W \end{cases}$$

$$Y_{i,s} = \begin{cases} 1 & \text{If Plant i is connected with milk center } \mathbf{s} \\ 0 & O.W \end{cases}$$

Continuous variables are used to follow the product flows from plants to markets and the milk flows from distribution centers to plants. Thus, two groups of continuous variables are introduced:
Variables $X_{i,p,m}$ show the amount of product **p** processed in plant i_{th} and sold on market m_{th}, which range in the following boundaries:
$$0 \le (X_i)_{p,m} \le D_{m,p} \quad , \quad \forall i, \forall p, \forall m$$

Variables $Y_{i,s}$ accounting for the amount of milk bought by plant i_{th} from the distribution center s_{th}, varying in:
$$0 \le (Y_i)_s \le M_s \quad , \quad \forall i, \forall s$$

And variables $Y_{i,s,p}$ accounting for the amount of milk bought by plant i_{th} from the distribution center s_{th} *to producing product **p***.

Product basket Variables:

The product basket variables are used to define the product portfolio of each dairy firm. They determine the amount $QP_{i,p}$ of each product **p** that must be processed in each plant **i$_{th}$** within the horizon **H**. These variables depend on the control variables χ, **Y**, **X** and **Y**.

Byproducts Variables:
The byproducts variables are used to define the byproducts which produce along end products processing. $B_{i,p}$ accounting for the amount of byproduct produce in plant **i$_{th}$** along product **p** processing.

Model
In the current model we assume that demand has uncertainty and depends on price variation and influence by incoming raw material fluctuation.

1. <u>Mass balance of the subsystem dairies – markets.</u> These equations follow up that no stocks accumulation will take place in each plant:

$$QP_{i,p} = \sum_{m=1}^{M} (X_i)_{P,m} \cdot \chi_{i,p,m} \quad , \quad \forall P, \forall i \tag{1}$$

2. <u>Dairy mass balance equations.</u> Using the average product yields, they determine the required, amount of whole milk Q_i to produce all products in each dairy:

$$Q_i = \sum_{p=1}^{P} \frac{1}{YF_p} \cdot QP_{i,p} \quad , \quad \forall P, \forall i \tag{2}$$

3. <u>Mass balance of the subsystem dairies – milk distribution centers.</u> These equations preserve dairies from milk accumulation:

$$Q_i = \sum_{s=1}^{S} (Y_i)_s \cdot Y_{i,s} \quad , \quad \forall i \tag{3}$$

Constraints
1. <u>Product portfolio feasibility constraints</u>:
Milk processing centers, as typical multipurpose batch plants, which are comprise mainly batch or semi-continuous units of different types and sizes, such as milk-separators, pasteurizers, vat-reactors, packing machines etc.
Each processing center provides opportunity for different sets of milk products to be manufactured simultaneously within some horizon of interest-H and schedules play an important role in it.

Each product uses different groups of plant units to perform respective production tasks, resulting in a number of potential production routes. Depend on the assignment and amount of product that should be manufactured, the existing units' capacity is shared by products and applying at different times within the horizon. Consequently, the time may be used as a flexible measure to evaluate the allocated plant capacity among products. Aiming to establish the proper framework of product portfolio for each dairy, in this paper we propose employing the time resource distribution of units' capacity within the horizon-*H*. To describe the proposed working frame we suppose that *P* different products, (p=1, 2, …, P), must be processed in the dairy and their amounts constituting the portfolio are QP_p [tons]. Further, the plant is represented by its superstructure, where all production units belonging to a given type-*n (n= 1, 2, ..., N)* are gathered in common processing **nodes**. Each node has a volume U_n determined as a sum of volumes of the respective units. Additionally, we assume that manufacture of each product passes through all processing nodes. If a product does not use units of a given type, a fictitious processing task for it is introduced, in order to connect it with the unused processing node. Thus, the number of processing tasks for each product becomes equal to the number of processing nodes. The size factors – $SF_{p,n}$ [m^3/ton] are given for the tasks of all products. They represent the "volume" of material that must be processed in the corresponding tasks to manufacture a unit

mass of target products. Respective processing times- T_n [h], which, if required, include an average estimation for the corresponding set-up time, are also given. For the fictitious processing tasks both, the size factors and processing times are assumed equal to 0. What follows that, for each processing node, the sum of products time assessments has to be less or equal of the horizon-*H* (Banchava and et al., 2006):

$$\sum_{p=1}^{P} SF_{p,n}\, QP_{i,p}\, \frac{T_{p,n}}{U_{i,n}} \leq H\,, \quad \forall n, \forall i \tag{4}$$

Additionally, because of all processing nodes are involved in each product manufacturing, it is also necessary that, for each product, the sum of the time assessments over all nodes would be less or equal of the horizon length:

$$\sum_{n=1}^{N} SF_{p,n}\, QP_{i,p}\, \frac{T_{p,n}}{U_{i,n}} \leq H\,, \quad \forall p\,, \forall i \tag{5}$$

Satisfaction of all the above constraints for each dairy product results in a feasible working frame of products' portfolio.

2. <u>Market constraints.</u> They ensure that amount of product **p** processed in all plants and sold on market **m** is less or equal to its market demand:

$$\sum_{i=1}^{I} (X_i)_{p,m} \cdot \mathcal{X}_{i,p,m} \leq D_{m,p}\,, \quad \forall m, \forall p \tag{6}$$

3. <u>Milk distribution centers constraints.</u> They guarantee that milk bought by plants from each milk center **s** is less or equal of its capacity:

$$\sum_{i=1}^{I} (Y_i)_s \cdot \mathcal{Y}_{i,s} \leq M_s\,, \quad \forall s \tag{7}$$

4. <u>Byproducts production constraints.</u> The volume of a BP obtained from the production of EP at a plant **i** should equal the multiplication between the volume of the EP produced and the fraction of that BP obtained while producing of the desired product **p**. If EP produced then BP probably produced (**M** is a large coefficient). $Fraction_{i,p}$ Is the participation rate of byproducts in the processing process, so if the value of this coefficient is zero, that is, byproducts are considered as food waste and discarded. The higher this coefficient means, the byproducts are considered to be nutritious and are used in order to produce a new product due to the capacity of the processing facility's equipment and infrastructure.

$$(B_i)_p = Fraction_{i,p} \times (QP_i)_p \tag{8}$$

$$(B_i)_p \leq M \times \mathcal{X}_{i,p} \tag{9}$$

Objective Function
The profit of dairy complex is used as an objective function. It is determined as a multi objective function which every function related to a coefficient and is defined as below. The numerical value of the coefficients of the objective function is defined according to the importance of each of the sections of the objective function. For example, the importance of the transportation in the dairy supply chain because of high perishability of RM and products, is more than usual.
Profit of dairy complex is subject to maximization and is determined as the difference between the incomes from sold products and milk and production costs.

$$F_1 = \sum_{i=1}^{I}\left[\sum_{p=1}^{P}\sum_{m=1}^{M}(X_i)_{p,m}\cdot\mathcal{X}_{i,p,m}\cdot C1_{m,p} - \sum_{p=1}^{P}C2_{i,p}\sum_{m=1}^{M}(X_i)_{p,m}\cdot\mathcal{X}_{i,p,m} - \sum_{p=1}^{P}C2_{i,p}(B_i)_b \right.$$
$$\left. - \sum_{s=1}^{S}(Y_i)_s\cdot\gamma_{i,s}C3_s\right] \tag{10}$$

Index of transportation cost is subject to minimization:

$$F_2 = \sum_{i=1}^{I}\left[\sum_{s=1}^{S}C4_{i,s}\cdot L1_{i,s}\cdot(Y_i)_s\cdot\gamma_{s,i} + \sum_{m=1}^{M}C5_{i,m}\cdot L2_{i,m}\cdot\sum_{p=1}^{P}(X_i)_{p,m}\cdot\mathcal{X}_{i,p,m}\right] \tag{11}$$

Using (10-11) the following multi-objective criterion is proposed $\phi = MAX\,(F_1, -F_2)$. The corresponding weighted multi-objective function is:

$$MAX\,(\alpha_1 F_1 - \alpha_2 F_2), \qquad where\ \alpha_1 + \alpha_2 = 1 \tag{12}$$

4. Stochastic Optimization of Case Study
4.1. Case description
Iran's Kurdistan province with an area of 28200 square kilometers is equivalent to 1.7 percent of the total area of Iran in the west of this country. The province is located on the slopes and plains of the middle of the Zagros Mountains (Fig. 4). Animal husbandry is one of the oldest activities in the province due to its favorable natural conditions, lush meadow and rich vegetation as well as favorable climatic and topographic characteristics. Lately, many residents of villages and even cities have been busy with it. Despite of the high capacity of livestock farms in Kurdistan province and the high number of livestock, including heavy and light livestock, a significant portion of dairy consumption is imported from other provinces, this is while the province should be the exporter rather than the importer, on the other hand, there are a million and 4 hundred rangelands of good quality, most of which are first and second grade, as well as the availability of suitable hay and healthy food for livestock in the province, large dairy processing units do not fit the conditions of the province. This has made dairy units more traditional. Initial studies show that the supply chain of milk and its supply to processing units due to structural reasons and the lack of a proper system of marketing agricultural products, as well as the lack of proper support for this sector, has not been consolidated. Due to lack of proper transportation system, road infrastructure, suitable locating of dairy farms, training for proper supply to factories and appropriate demand for dairy cattle (memorandum and contract), a significant portion of the dairy production (milk) of the province is supplied directly to dairy markets in the cities and is processed on a small scale and traditionally. For this reason, the number of dairy processing factories is not only very limited, but also has a very small variety in terms of the variety of products, and this has prevented these units from having the features of modern production. Even ask for supply of primary material (milk) from outside the province. In spite of the large number of livestock due to the excessive dispersal of these livestock, centralized and sanitary milk collection is not done correctly. The lack of standard milk collection centers is another problem in this chain. Considering the points mentioned about the dairy supply chain in Kurdistan province, this chain has been selected as the case study of this paper.

The case study comprises two dairies. In each of them three products – Drinking milk (P_1) (fat content 1%); Curds (P_2) (fat contents 1%); and Cheese (P_3) must be manufactured over the time horizon (24 [h]). The products could be sold on two markets, ($M=2$). The whole milk, with 3,2% fat content is used as a raw material. It could be bought from two distribution centers, (S=2).

The coming in dairy whole milk firstly passes the separation step when redistribution of milk fat and milk plasma carries out. As a result the skim milk and cream with 30% fat content are obtained. The skim milk used for Product 1 must have 1% fat content, while for Product 2 - 0.233%. The whey obtained as a major byproduct is produced

during cheese processing. Whey is the major byproduct of the dairy industry, produced in large quantities and usually disposed of causing major environmental pollution, due to its high organic load that makes treatment cost prohibitive. Cheese effluents represent a significant environmental impact in the dairy industry because of their physicochemical characteristics, namely, minerals (0.46-10%), total suspended solids (0.1-22 kg m^{-3}), pH (3.3-9.0), phosphorus (0.006-0.5 kg m^{-3}), Total Kjeldahl Nitrogen (TKN) (0.01-1.7 kg m^{-3}), organic load (0.6-102 kg m^{-3}), etc. The high value of organic matter is caused by the lactose (0.18-60 kg m^{-3}), protein (1.4-33.5 kg m^{-3}) and fats (0.08-10.58 kg m^{-3}) contents. This organic matter is around 99% biodegradable (Ergüder et al., 2001).

So, we react with this kind of product as an important issue which can be used in other parts of process.

Figure 4. Map of Iran's Kurdistan

4.2. Assumptions

The finished products are delivered to satisfy markets with fluctuated demand. Demand basically depends on price variation. In our analysis we have simplified several of the aspects concerning the planning problem for the milk processing plant. First we assume demand is deterministic and solve the model based on the nearest SC's data, after that we consider stochastic conditions and factors which affect SC's demand, use a certain stochastic optimization procedure to analysis this case study (Birge and Louveaux, 1997). Also, in part of the analysis we assume byproducts which produce along the processing of end products can be used as raw material or new end product therefore they cannot be discarded. Due to the analysis we assume three scenarios. Fig. 4 shows the map of model analysis. In first scenario, deterministic condition is considered in the way which demands and other parameters are certain. The other scenarios consider uncertainty in supply chain conditions. Demand depend on price variations so we assume demand is stochastic and rely on market price. The amount of raw material incoming to the plants and the end product market prices are considered to be uncertain. Raw material (RM) coming to the plant because of high perishability must be used exactly on the day so it's impossible to maintain them. On the other hand, quantity and quality of raw milk depends on season and climate changes. Therefore, seasonal feature of incoming raw material affect quality and quantity of end products and also byproducts. So we consider that raw material incoming to the dairy supply chain is uncertain. In the following, we will investigate two case-instances with respectively, uncertainty in the market prices and the incoming raw material. To analyze the impact of uncertainty, we also find the Value of the Stochastic Solution (VSS) with the resulting profits from the expected value problem given the uncertainty. In this analysis, we consider three scenarios in two different conditions; first we consider byproduct (Whey as a major of them) as an important part of processing, later we eliminate the role of byproduct in processing procedure and then analyze the model in the above three scenarios (Fig. 5). Table 2 and Table 3 show the results of this analysis. We investigate these results in next subsections. In table 2, calculations of stochastic conditions have started based on data collected from case study in the spring. The calculations continued in next seasons until next spring. When considering byproducts, the dairy market is targeted and demand and price of traditional products which have made from whey, are considered as an attachment of cheese. In other words, the higher use of whey as cheese byproduct, will affect the price and demand of cheese. Note that byproducts in this study are not considered as separate products. It is clear that in order to collect data on the implementation of favorable scenarios in developed model; we refer to traditional processing centers. In these centers, whey is traditionally converted into products and offered to consumers.
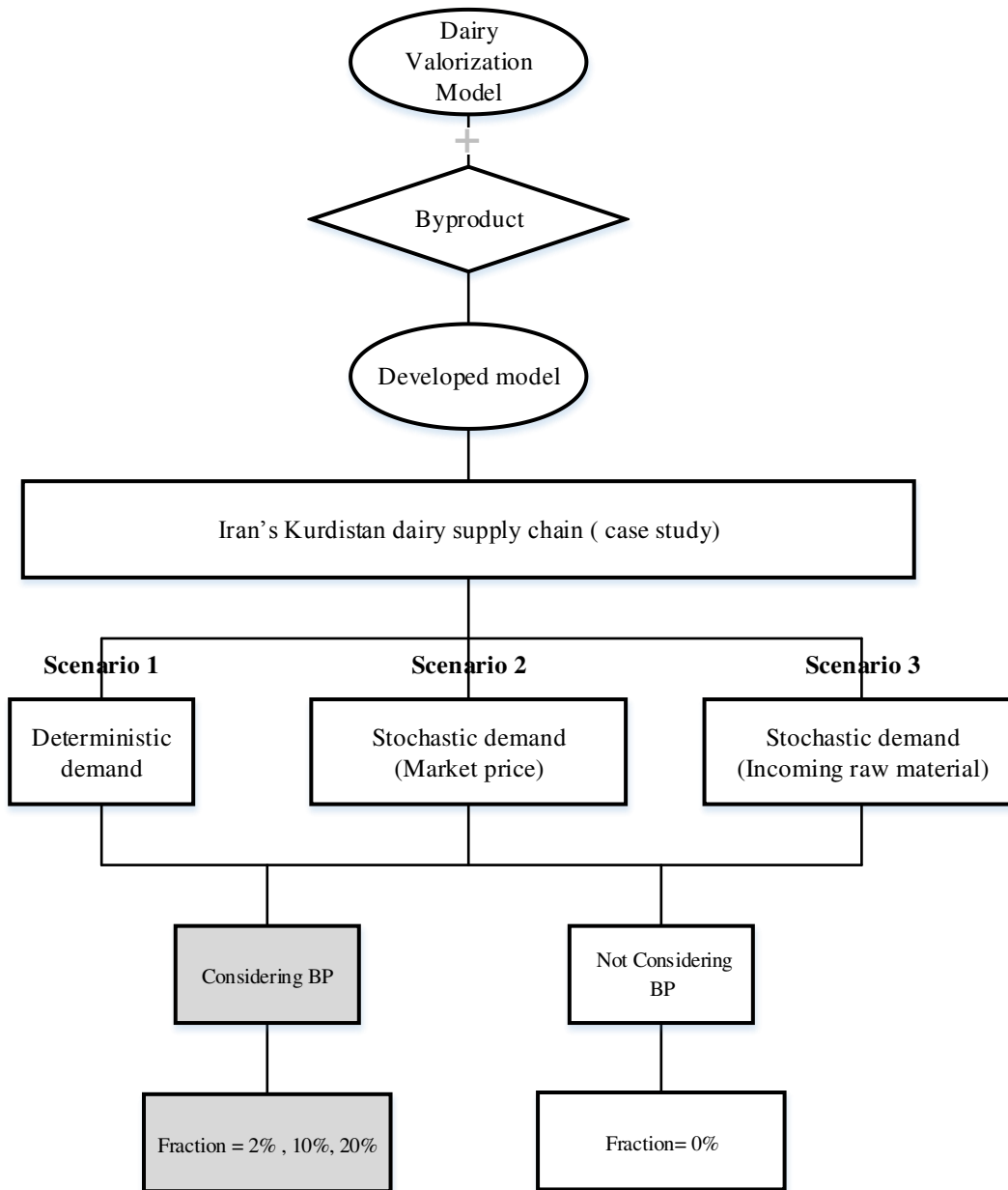
Figure 5. Map of model design and analysis

Table 2. Numerical results of model in stochastic conditions

Percentage of Whey's participation in processing		Average cheese price over the past four seasons	Changes in the demand for cheese products due to the seasonality of raw milk characteristics	SC's Profit changes
Favorable conditions	Fraction 20%	4.58 k 2.65 k 2.05 k 1.73 k	25.34 k 22.06 k 19.75 k 17.88 k	25.31 k 21.87 k 19.51 k 17.59 k
	Fraction 10%	6.22 k 3.72 k 2.95 k 2.54 k	24.87 k 20.93 k 18.12 k 15.78 k	23.85 k 19.16 k 15.83 k 13.07 k
	Fraction 2%	4.53 k 2.61 k 2.02 k 1.71 k	12.74 k 11.08 k 9.94 k 9.01 k	12.71 k 11.03 k 9.88 k 8.94 k
Existing condition	Fraction 0%	4.5 k 2.6 k 2.01 k 1.7 k	8.5 k 11.08 k 6.64 k 6.02 k	6.37 k 5.54 k 4.97 k 4.51 k

Table 3. Summary of the analysis in the incoming raw material and market price with the nearest data

Scenario's number	Model's type	Consider Byproducts	SC's Profit	Δ (The change rate in SC's profit)
1	Deterministic	Yes No	4,83k 4,75k	0.8k
2	Stochastic (Market price uncertainty)	Yes No	4.58 k 4.5 k	0.08k
3	Stochastic (Raw material uncertainty)	Yes No	25.31 k 6.37 k	18.94k

4.3. Uncertainty in the market prices

Fig. 6 shows the Iran's Kurdistan dairy supply chain profit based on price changes for the third product (cheese) under existing condition (Fraction$_{i,p}$ = 0%) and favorable conditions (Fraction$_{i,p}$ = 2%, 10%, 20%). As it was mentioned before, one of the most important and nutritious byproduct in dairy chain is whey, which is rich in protein and many other minerals and nutrients can be used as the primary ingredient for the production of new dairy products (Koutinas et al., 2009). On the other hand, because these products include production costs, the waste of these materials, in addition to the loss of food, will impose additional costs on SC. In this regard, in the study of the dairy supply chain of Kurdistan province, whey as a byproduct of cheese is considered and its impact on the processing is examined. As the byproduct's percentage of participation increases, due to the benefits of processing these nutrients, a higher percentage of production costs will be covered, which will lead to added value for the dairy supply chain and more satisfaction of both producers and consumers.

In the existing condition, whey is discharged from industry sections. By weighting and using this highly nutritious material in desired scenarios, we looked at changes in the profit function of the supply chain and saw the improvement in this function. As can be seen in Fig. 5, changes in the chain profit function are concave in relation to

the increase in the price of the cheese product, and by increasing in the percentage of byproduct (whey) participated in the processing, it has climbed.

Since the price of raw milk is determined by the government in Iran, subsequently, the price of processed milk has been fixed and its change goes to government rules and regulations. So in three scenarios (Deterministic and Stochastic) we assume that processed milk price is constant. But in the case of other dairy products which their price will be determined by the corporation or processing center, can be vary. Obviously, pricing policy in the competitive market depends on several things and affects market demand. So, competitive market features lead to different and variant pricing policies which are adopted by processing centers, which, of course is not within the scope of this research. Therefore, other kinds of dairy products have variant market prices and this leads to uncertainty in market prices and demand. The price fluctuations affected by government policies and many other kind of economic circumstances. This feature can be seen in the results of modeled supply chain's profit.

In the case of existence of upstream force about production combination or product price, when these rules have conflict with firm's profit, firm try to identify an escape route. For example in dairy firms which milk price is defined and imposed by government, but there isn't any control on the cost price of other dairy products, dairy firms try to identify the best portfolio due to optimize their profit function and in the way the major constraint is market circumstances. This situation also occurs if there is a limitation in processing equipment.
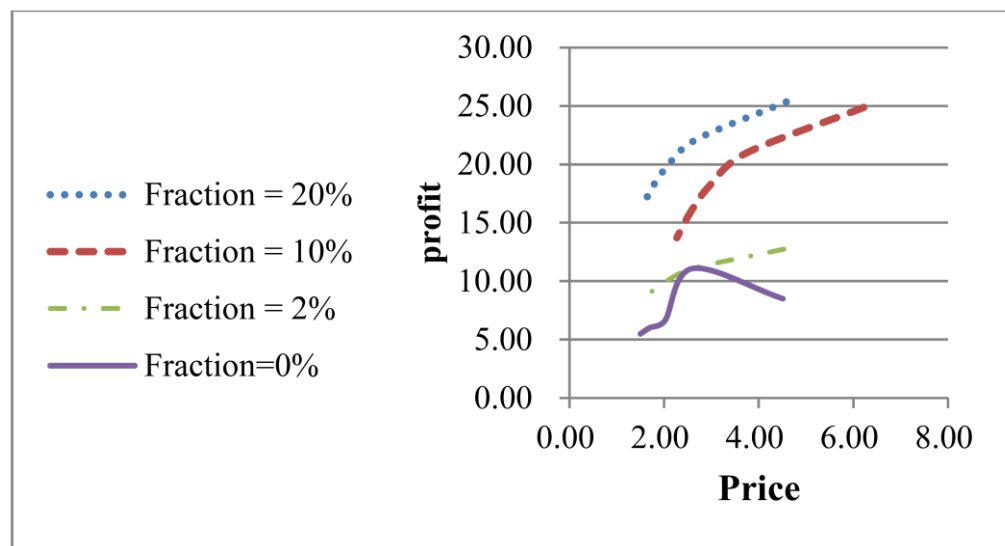

Figure 6. Changes in the level of dairy chain profit due to changes in the price of a third product in different conditions of byproduct participation

4.4. Uncertainty in the incoming raw material

As mentioned in 4.2. Section, quantity and quality of incoming raw materials in dairy supply chain depend on several conditions such as seasonality. As can be seen in the result of analysis (Table 4), in the case of stochastic scenarios, supply chain's profit is significantly lower than deterministic scenario. Existence of uncertainty in incoming RM because of seasonality, poor transport infrastructure and lack of proper management in the entire Iran's Kurdistan dairy supply chain, has many significant impacts on supply chain's profit.

Fig. 7 shows the changes in the profit function in terms of qualitative and quantitative changes of input RM in different seasons. These seasonal changes affect the quality of the EP and BP and lead to a shift in demand for these products. Seasonal variations in RM lead to a rather unpredictable trend in the profit function. Again, the profit function when byproducts is discarded (Fraction$_{i, p}$ = 0%) is lower than the favorable scenarios (Fraction$_{i, p}$ = 2%, 10%, 20%). The shape of the objective functions in this scenario when raw material changes are not concave, like the second scenario, but linearized. As can be seen in the result of analysis, uncertainty in the incoming raw material affect the supply chain's profit when byproduct is considered or not.

Due to the importance of milk health, it's necessary to reflect this issue in the model according to the different kind of supply sources (traditional and industrial). On the other hand, market applicants especially in the traditional

regions, unexpectedly lead their demand to the traditional supply sources and moderate-to-upper-middle class population is the main consumer of industrialized products.

Since there is a kind of distrust in the traditional Iranian societies in relation to industrialized products, the demand for pasteurized milk for home-made products has decreased, which is why people's demand for traditional dairy products has been driven. These issues all relate to the seasonality of the characteristics of RM and the quantity and quality of this raw material which affect the demand. These conditions are a major threat to social health and it also damages the country's economy and is an obstacle to industrialization.

The same thing has forced industrial units to maximize their capacity in order to justify the existing of these units. As in some of these units, it is reported that even dry milk is used to produce other dairy products. Therefore, these cases are the source of uncertainty or risk activity in the processing and consuming sector.

As a solution, the change from traditional livestock to industrial livestock, in addition to controlling livestock forage in different seasons can be mentioned, which leads to a reduction in the contagious diseases of the livestock and reduction in RM features volatility consequently, the improvement of the quality and quantity of raw milk.
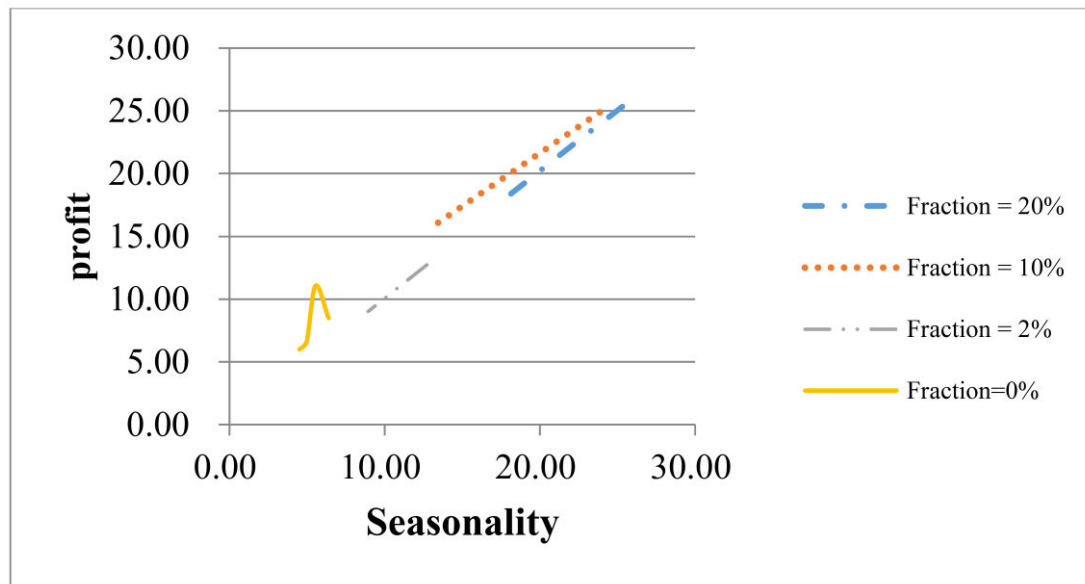

Figure 7. Changes in the level of dairy chain profit due to changes in the seasonality features of RM (third product) in different conditions of byproduct participation
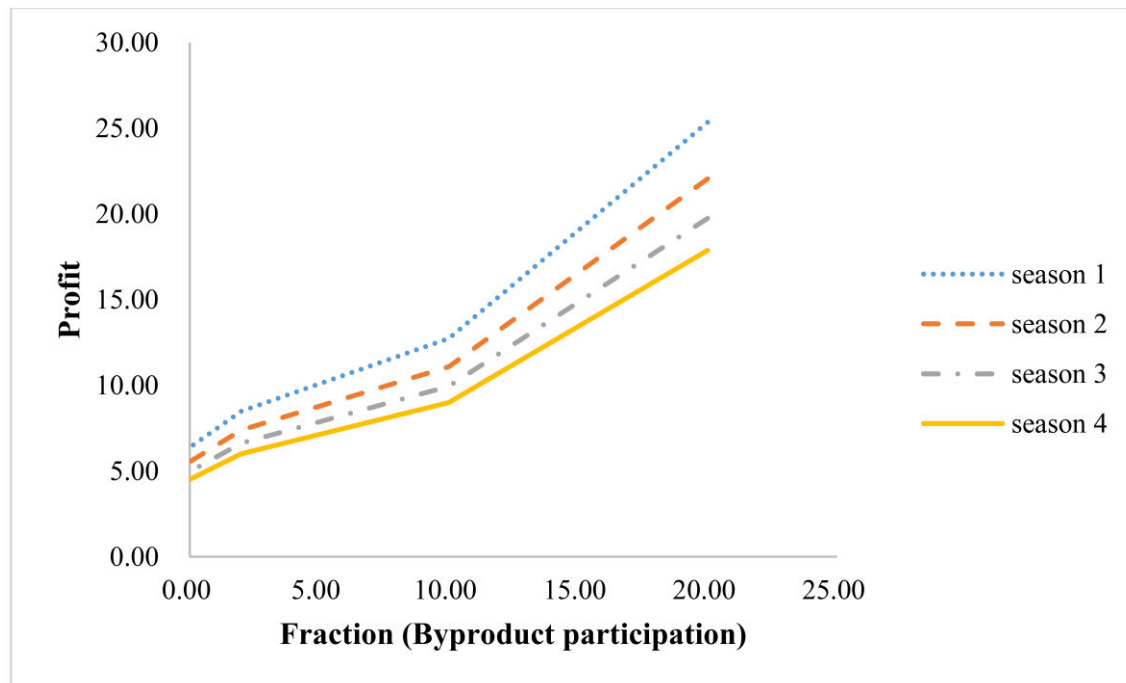
Figure 8. Changes in the level of dairy chain profit due to changes in the participation ratio of byproduct (whey) in industrial processing

5. Conclusion

In this paper, by presenting and developing a new model in dairy supply chain valorization, we have taken a step towards reducing food waste, reducing supply chain costs, and improving the profit function and the overall structure of the chain, while considering the importance of byproduct role in dairy supply chain streams. In order to analyze the model, three different scenarios under different conditions were designed; considering byproducts and not considering them. In the first scenario, the assumption of demand certainty for dairy products was considered. In this way, the demand was considered without dependence on different factors, and then under different conditions, the SC's profit was calculated. In the second and third scenarios, we went out of certainty and entered the uncertainty space. Iran's Kurdistan dairy supply chain studied as a case and its demand uncertainty space has analyzed. The results of analysis show that considering byproducts has an important role in increasing supply chain profit and also reduce food waste. The two most important factors affecting dairy products demand are the dairy products price and the quantitative and qualitative characteristics of these products. Price products fluctuation lead to demand uncertainty which it results from Iran's economic circumstances and incoming RM variations depends on the seasonality of the RM characteristics; subsequently they affect the dairy supply chain profit. In the current situation of case study, with regard to the non-consideration of byproducts in the industrial processing sector, these nutrients are discharged from the cycle. On the other hand, consumers are pushing for the purchase of dairy products traditionally processed in villages or in traditional processing centers in the cities. This process will damage the economic and industrial cycle of the region and will hinder the growth of the industry, as well as the non-pasteurizing process of this system, there is a danger to the social health. In favorable scenarios, when the percentage of byproduct participation in the processing increases, we see an increase in supply chain profit. By changing from definite space to stochastic space, the amount of profit function has decreased in all conditions, which indicates the importance of managing and controlling the factors affecting demand, including the price and seasonality. As a solution, construction of industrial dairies in different regions of the province can be mentioned. By mechanizing the production of RM and collecting livestock from the villages, an important step towards the development of the industrial sector and the reduction of the traditional portion of dairy processing and improving the quality and quantity of RM will be taken. The price volatility of dairy products depends on different factors; the reduction of these fluctuations will reduce the effects of this factor on demand, reduce uncertainty and ultimately improve supply chain profit.

A suggestion for future research in this area could be the development of a new portfolio of industrial products in the dairy supply chain of Iran's Kurdistan province. In order to change the demand from the traditional sector to the industrial sector and thus to contribute in economic growth, it is possible to use byproducts in the production of new products at processing centers. Rooting and identifying infrastructure gaps in the supply and distribution processes of the dairy supply chain will lead to improved quality and quantity of dairy products processing, help the country's economy, increase customer satisfaction and reduce food waste.

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