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# Examining the production amount of milk and dairy products using network analysis in Turkey

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**Abstract**

Among the sub-branches of the livestock industry in Turkey, milk and dairy product sector is one of the most active production areas. It is essential to examine the supply structure of the milk and dairy product sector and reveal the relations between the production amounts of the products to understand the overall structure of the sector. We determined the pattern network structures based on the amount of raw cow milk entering the industry and the production amounts of six products between 2010/01 and 2020/09. In addition, we studied the product-based development of the sector. The findings obtained from the network analysis of the production amounts of milk and dairy products indicated a relationship between the products and their interactions with each other. The amount of raw milk entering the production process was located in the center and displayed a positive relationship with all products it interacted with. The amount of raw cow milk entering the production process and the amount of cow cheese produced affected other products included in the network. In addition, among the products produced, the production amounts of ayran and yogurt exhibited the highest correlation coefficient with a moderate positive correlation value (0.609). The resulting social network graph provides important clues about the general production understanding of Turkey's dairy sector and consumer preferences in the market.

**Keywords:** raw milk; dairy products; dairy industry; network analysis; Turkey.

**Practical Application:** It gives information about the market structure of developing countries by showing the general production and consumer preferences regarding milk production and dairy products in Turkey with an innovative method.

## 1 Introduction

Milk and dairy products are an essential constituent of the diet of billions of people worldwide (Visioli & Strata, 2014). Milk and dairy products are essential dietary items that fulfill important functions regarding the protection of human health (Lago-Sampedro et al., 2019; Marangoni et al., 2019; Martins et al., 2018). Dairy consumption makes the most significant contribution to calcium intake (Shkembi & Huppertz, 2021). The functions fulfilled by dairy products as functional goods are mentioned in many studies. Intake of milk and dairy products contributes to meeting nutrients and may protect against the most prevalent, chronic non-communicable diseases (Thorning et al., 2016). It is highlighted that consumption of Probiotic Prato cheese attenuates the development of renal calculi (Martins et al., 2018). That L. casei 01-added Probiotic Minas Frescal cheese has desirable effects on hypertensive overweight women's physicochemical and bioactivity characterization and hematological/biochemical parameters (Sperry et al., 2018). That yogurt consumption supplemented with 1000 IU vitamin D by diabetic patients with vitamin D deficiency and hyperlipidemia increases serum lipid indices (Mostafai et al., 2019). High-quality milk can be used as a carrier for functional components such as prebiotics and bacteria (Verruck et al., 2019a). Quality goat milk can be used as a carrier for functional components such as prebiotics and bacteria (Verruck et al., 2019b). Recent research shows that consumption of milk and dairy products positively affects human health and reduces risks. Particularly noteworthy is the recognized activity of CLA in inhibition of cancer, atherosclerosis, and an improvement of immune functions as a whole (Elwood et al., 2010).

In Turkey, the dairy industry businesses include the purchase of raw milk from numerous dairy cattle enterprises, processing the purchased raw milk, and marketing it through wholesalers and retailers. This structure allows the dairy industry to maintain bargaining power in the market (Günlü, 2011).

In 2019, 22,960,379 tons of milk were obtained from all species in Turkey. Of the milk produced, 90.51% was from cattle, 6.63% was from sheep, 2.51% was from goat, and 0.35% was from buffalo milk (TÜİK, 2020). Although the raw milk (cow's milk) produced between 2013 and 2019 increased by about 25%, the raw milk transferred to the industry did not increase at the

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same rate. The amount of raw milk purchased by the industry from dairy cattle enterprises witnessed the highest levels in May and the lowest in November, which is in parallel with the increase in milk production. In the dairy sector in developed countries and several European countries, almost all raw milk produced is transferred to the industry (Akin, 2020). In 2019, only 45.74% of the raw milk produced in Turkey was transferred to the industry (TÜİK, 2020). This rate was 99.5% in the USA, 95.5% in Germany, and 81.75% in Poland (USK, 2018). The transfer of raw milk to the industry at such low rates in Turkey is a hurdle to the progress of the sector and the conversion of milk into products with high added value (Akin, 2020).

The annual average production in the dairy industry between 2010 and 2020, examined by this study, was 595,329 tons of cow cheese, 1,095,402 tons of yogurt, 598,217 tons of ayran, 1,351,352 tons of drinking milk, 38,976 tons of milk powder, and 50,537 tons of butter (TÜİK, 2020).

The complexity of national and international trade structures prevents trade flows making it impossible to quickly resolve complex trade links (Pinior et al., 2012a). Moreover, this applies to the production of basic foodstuffs, such as raw milk that is processed into different products and subjected to national and international trade. In a free market, strong or weak relations may emerge between the production amounts of raw milk, which is the primary raw material of dairy industry enterprises, and the final products, such as cheese, yogurt, and ayran. These relationships allow each product to be produced at a certain rate, based on the dynamics of the market. To examine the production amounts of the milk and dairy product sector, which has such a complex production structure, in addition to time series analysis (Akin et al., 2020; Kaygisiz & Sezgin, 2017), network analyses can be used. For example, a network analysis was used to examine the changes in the structure of dairy product trade in the European Union (EU) countries between 2001 and 2012 (Benedek et al., 2017). Network analysis, which is also used extensively in social sciences, has been recently applied to data in the field of livestock because it can reveal the relationship between variables visually (Rhemtulla et al., 2016; Pinior et al., 2012b; Mekonnen et al., 2019).

Networks provide a conceptual framework that can demonstrate the relationships between constituent elements (raw milk, cheese, yogurt, etc.) (Bigras-Poulin et al., 2006). This method allows the visualization of the milk and dairy product market by identifying strong and weak links in the network, determining the intensity of interaction in the network, and revealing the roles of products in the network. In other words, graph theory, which provides a rich analytical framework, can be used to examine the relationship between the amounts of raw milk and final products (Foulds, 1992) and the direction of relationships between the components of these products (i.e., from the raw milk node to the yogurt node) is represented by a graph (Bang-Jensen & Gutin, 2002).

This study aims to reveal the pattern network structure of the relationship between the amount of raw cow milk entering the industry and the production amounts of six products (cow cheese, ayran, yogurt, drinking milk, milk powder, and butter) between 2010/01 and 2020/09, as well as to reveal the characteristics of this network.

## 2 Motivation

Many parameters do not give meaningful and accurate results when statistical analysis is made with the classical freeclass approach. In this case, it was intended to use multivariate methods. Pattern analysis was attempted without the "p" inflation. For these reasons, the main motivation of the study is to determine a situation through artificial intelligence algorithms.

## 3 Materials and methods

### *3.1 Dataset*

The dataset consisted of the amount of raw cow milk purchased by dairy industry enterprises from dairy cattle enterprises between 2010/01 and 2020/09 and the monthly production amounts of cow cheese, ayran, yogurt, drinking milk, milk powder, and butter produced in this period. Data on the amount of raw cow's milk and dairy products were obtained from the monthly dairy statistics department of TURKSTAT's central distribution system (MEDAS) (TÜİK, 2020).

### *3.2 Analysis method*

We studied the characteristics of the pattern network of the relationship between the amount of raw material (cow's milk) purchased by the dairy industry enterprises in Turkey and the amount of six dairy products due to production. A network analysis was performed to identify strong and weak links in the network to determine the density of interaction in the network and to reveal the roles of products in the network. JASP (JASP Team, 2020) (Version 0.14) [Computer software] was used to determine the structure of the relationship between products and for visualization.

The study determined the positions of raw cow's milk, cow cheese, yogurt, ayran, drinking milk, milk powder, and butter products in the network. Major centrality measures, namely, degree, betweenness, closeness, and influence centrality, as well as the density measures of networks, were determined to evaluate the links. Each of these centrality measures uses a different assumption for finding the most effective node (product). Therefore, each measure adopts a different approach that makes any node effective or central in a network. The products are positioned using the Fruchterman–Reingold layout algorithm organizes the network according to the strength of the links between nodes (Fruchterman & Reingold, 1991). We used these criteria to determine which product was important, effective, and most known.

The networks represent Gaussian graphical models; every item from each measure is defined as a 'node'. After controlling for all other items, the partial correlation between any two items is represented as an 'edge'. Green and red edges symbolize positive and negative partial correlations, respectively; the wider and more saturated the edges, the stronger the partial correlations are. The thickest possible links correspond to the maximum value of the strongest edge in the network (this is displayed below the networks as maximum), and the closer the edge weights get to 0, the less saturated and smaller the edge is. To control spurious connections, which occur when two variables have no relationship but are statistically linked, we used a regularization method that resulted in a sparser and more interpretable network. Specifically, we utilized the 'graphical LASSO' algorithm as implemented in R's 'glasso' package. The glasso algorithm uses a tuning parameter controlling the network sparsity, which we selected by minimizing the extended Bayesian information criterion. There is no threshold necessary for the edges to be displayed; all edges that survive regularization are displayed within the networks. This regularization ensures that only the statistically meaningful edges are retained in the network and controls for Type 1 errors that may result from sampling error. An attempt was made to avoid the biases associated with the use of a single threshold, in order to allow a comparison of network characteristics between groups. Therefore, the relationship matrices were thresholded at a range of network densities in 0.01 steps (Dmin: 0.01: 0.50). Minimum density is when the networks of both groups are not fragmented. It is also the density at which paths exist between each node and other nodes. The chosen maximum intensity was 0.50 because after this threshold the plots are becoming more and more random (Hosseini et al., 2012). The following global network metrics are calculated at each of these thresholds: 1) characteristic path length and 2) clustering coefficient.

## 4 Results

Figure 1 shows the network of the amount of raw milk entering the production and the amounts of dairy products produced. The thickness of the line shows the density of the relationship between the products; the blue lines show the positive relationship between the products, and the red lines show the negative relationship between the products.

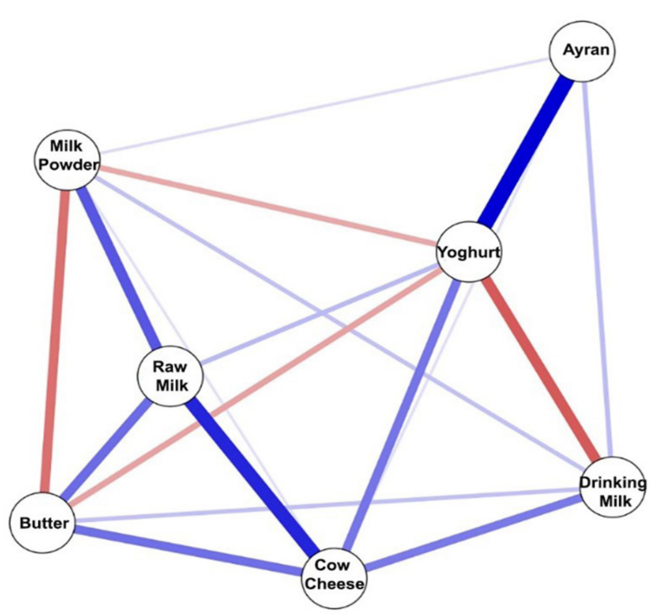


**Figure 1.** Network of products.

A graph is composed up of nodes (also called vertices) that are connected by edges (also called arcs or links). Analysis results showed the existence of more links between products, indicating positive relationships. Products such as, raw milk, which can be processed into other products, and yogurt, which is difficult to process into other products, displayed the most links. The final products were located outside the graph; the products considered as raw materials were located in the center, which is a striking feature of the network. Table 1 presents the introductory information for networking of the products examined within the scope of the study.

Based on the findings given in Table 1, the general structure of the network, we conclude that there exists a relationship between the amount of raw milk entering the production and the amounts of dairy products. In addition, the products interacted with each other. Four measures were used to determine the centricity levels of the products: degree centrality, closeness centrality, influence centrality, and betweenness centrality. Table 2 presents the centrality levels of the amounts of raw milk and dairy products.

Figure 2 presents the graph of centrality values examined for the amount of raw milk entering the production and the amounts of dairy products produced. Nodes indicate the product types, and links indicate the relationships between these products. The distance from one node to other indicates the degree of the relationship between products.

A clustering coefficient measures the local group cohesiveness and is defined for any vertex as the fraction of connected neighbors. These coefficients reveal the strength of the link between the products and their neighbors. Accordingly, Table 3 presents the clustering coefficients for the products.

Figure 3 presents the graphs of clustering coefficients for the amounts of raw milk entering the production and the amounts of dairy products produced.

Table 4 presents the correlation coefficients between the six products produced by the milk and dairy product industry and raw milk. Among raw milk and six products, the highest negative correlation was associated with yogurt.

**Table 1**. Introductory information for networking.

| Number of nodes | Number of non-zero edges | Sparsity |
|---|---|---|
| 7 | 18/21 | 0.143 |

**Table 2**. Centrality values of the network.

| Product | Betweenness | Closeness | Degree | Influence |
|---|---|---|---|---|
| Raw milk | −0.199 | 0.295 | 0.137 | 1.156 |
| Cow cheese | 1.196 | 1.569 | 0.789 | 1.505 |
| Yogurt | 1.662 | 1.030 | 1.622 | −0.724 |
| Ayran | −0.665 | −1.038 | −1.420 | 0.324 |
| Drinking milk | −0.665 | −0.842 | −0.718 | −0.582 |
| Milk powder | −0.665 | −0.718 | −0.442 | −0.939 |
| Butter | −0.665 | −0.296 | 0.033 | −0.740 |

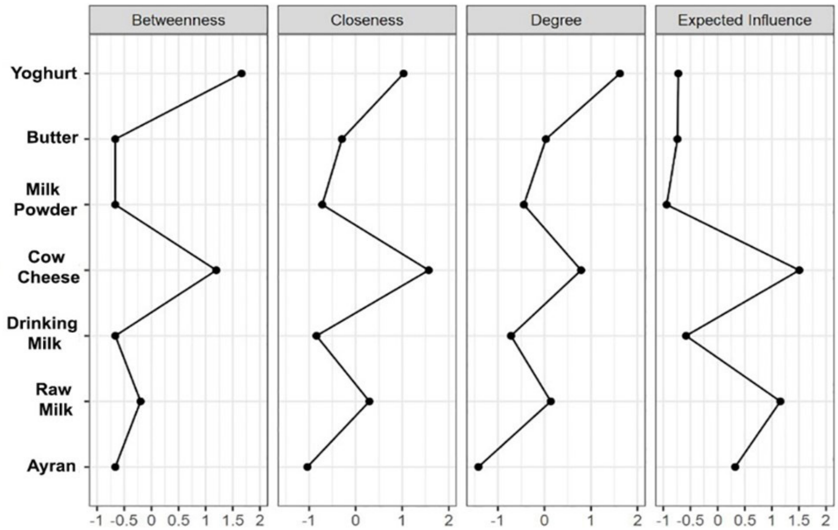


**Figure 2.** Centrality graph for the network.

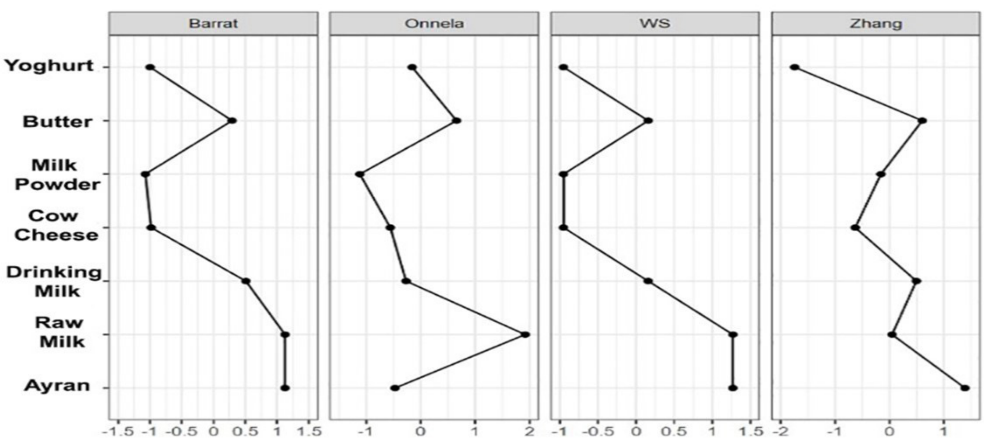


**Figure 3.** Graph of clustering coefficients for the network.

**Table 3**. Clustering coefficients for the products.

| Product | Barrat | Onnela | WS | Zhang |
|---|---|---|---|---|
| Raw milk | 1.126 | −0.472 | 1.270 | 1.388 |
| Cow cheese | 1.126 | 1.919 | 1.270 | 0.046 |
| Yogurt | 0.510 | −0.270 | 0.159 | 0.494 |
| Ayran | −0.982 | −0.559 | −0.953 | −0.631 |
| Drinking milk | −1.074 | −1.119 | −0.953 | −0.157 |
| Milk powder | 0.293 | 0.657 | 0.159 | 0.603 |
| Butter | −0.999 | −0.157 | −0.953 | −1.744 |

**Table 4**. Correlation coefficients between products.

| Product | Raw milk | Cow cheese | Yogurt | Ayran | Drinking milk | Milk powder |
|---|---|---|---|---|---|---|
| Cow cheese | 0.518 | | | | | |
| Yogurt | 0.164 | 0.325 | | | | |
| Ayran | 0.000 | 0.072 | 0.609 | | | |
| Drinking milk | 0.000 | 0.315 | −0.390 | 0.156 | | |
| Milk powder | 0.398 | 0.070 | −0.204 | 0.084 | 0.144 | |
| Butter | 0.348 | 0.341 | −0.221 | 0.000 | 0.145 | −0.340 |

## 5 Discussion and conclusion

In Turkey, raw milk is processed into final products due to the labor-intensive production of several producers, and the activities of a small number of plants and dairies. Between 2013 and 2019, raw milk production increased by 25%, whereas the amount of raw milk transferred to the industry increased by 20% (Akin, 2020). One of the reasons for the inadequate increase could be oligopsony–oligopoly market order between raw milk producer, milk industry, and consumers (Hatırlı & Özkan, 2004; Günlü, 2011; Akin, 2016). In addition, Turkey's dairy sector market has witnessed fluctuations in both milk and feed prices, which could have adversely affected the profitability of dairy farms, as has been the case in the USA recently (Wolf, 2012). These fluctuations negatively affect several stakeholders in the sector, especially raw milk producers.

The variety of dairy products produced depends on the marketing network of the companies and the popularity of the regional products produced. Unlike other agricultural activities or industrial products, the raw milk production process is unsuitable for instant production cuts. The supply of raw milk produced in farms should not be interrupted, and the raw milk produced should be processed into final products in line with the demands. Therefore, production should be planned correctly and timely, according to market dynamics.

The prices of products are related to each other due to the substitution effect of products and the supply–demand relationship, causing all products to be in a complex system as part of a whole (Sun et al., 2018). In addition to considering the supply–demand relationship based on the price, examining the complex structures of the relationships between the amounts of supplied products reveals the relationships among the products in the market.

The fact that raw milk has the highest positive relationship with cow cheese (Figure 1) provides important clues about the general structure of the sector. The production density of cow cheese in Turkey is attributed to small regional enterprises and dairies. This mode of production can be defined as local agri-food systems: these enterprises are small-scale enterprises specializing in a particular food product (such as Kars Gruyere cheese, Ezine cheese) (Requier-Desjardins et al., 2003; Thompson & Scoones, 2009). The majority of these small enterprises in Turkey are specialized in cheese production. An analysis of dairy industry enterprises revealed that 13 firms possessed close to 40% of the market share, whereas 1,725 small-scale enterprises (dairies) had 39.43% of the market share (Güneş, 2013). Although numerous small enterprises have a lower market share than 13 firms, they are concentrated on certain products, making them important in the milk and dairy products market. There are two main features that dairy industry businesses can derive competitive benefits from sustainability practices: cost leadership and product differentiation (Ghadge et al., 2020). The long-term storage possibility of cheese, longer shelf-life, and high milk equivalent contributes to the concentration of dairy enterprises on cheese production in Turkey. In addition, the raw milk-cow cheese (dark blue) relationship shown in Figure 1 emerges because the cheese demand is distributed throughout the year due to consumer preferences. Thus, dairies can more easily control their production and marketing costs by selecting to produce a single product (e.g., cow cheese). The product variety mentioned is not preferred by small enterprises such as dairies due to reasons such as insufficient infrastructure and marketing channels (Ghadge et al., 2020).

The milk powder produced within the scope of the inward processing regime (IPR) and the incentives provided to this product are effective in the dense positive relationship (Figure 1) between milk powder and raw milk. In recent years, an increase in the amount of butter production occurred due to an increase in the varieties of dairy products such as semi-skimmed or skimmed, pasteurized milk, ultra-high temperature (UHT) milk, and yogurt. The weak positive relationship between drinking milk and butter shown in the network analysis supports this idea. The finding that yogurt had the densest relationship with ayran in the network could be explained by the fact that these two products show parallelism in line with consumer preferences, depending on the season. However, the negative and dense relationship between yogurt and drinking milk can be explained by the increase in drinking milk production in periods when the supply of raw milk is high and when there is less demand for yogurt than during other periods.

The degree of sparsity, one of the most used criteria in graph theory, is obtained by subtracting the ratio of all existing links in the network to the maximum possible links from 1. The degree of sparsity of a network lies between 0 and 1 (Lowes et al., 2007). As can be seen in Figure 1, the total number of links among the products was 18. In contrast, the maximum number of links for this network is 21. Accordingly, the degree of sparsity was 0.143 (Table 1). The degree of sparsity is sufficient for a network with seven products, indicating that the degree of sparsity was low, and there was a high density in the network of raw milk and dairy products. Therefore, the products produced in the dairy industry and the raw milk entering the industry are strongly linked with each other and cannot be considered separately.

When we evaluate the amount of raw milk entering the production process and the amounts of dairy products produced in the context of centrality measures, yogurt and cow cheese were the products with the highest betweenness centrality (Table 2). Nodes with a high betweenness centrality are accepted as nodes that serve as a bridge between two or more clusters of nodes that cannot communicate with each other, and they have the potential to control the network (Saramäki et al., 2007; Watts & Strogatz, 1998; Boudin, 2013; Brandes, 2001). These products have a relatively more important position in the milk and dairy product market. Accordingly, among the products, yogurt and cow cheese (Figure 1) are key products that are highly active in the network and serve as a bridge between other non-linked products. Considering this result in the context of the market, the two related products are produced by several enterprises in the sector. The production and demand intensity of cow cheese and yogurt are at the forefront, both on a regional and national scale, and cause enterprises that produce in this field and whose product range differs in the intersection clusters.

The degree of closeness indicates the closeness of a product with other products. The degree of closeness is defined as the inverse of farness, i.e., the sum of the shortest distances between one node and all other nodes. This value indicates that to which product another product will be most connected. In addition, it measures the independence or efficiency of the node (Boudin, 2013; Brandes, 2001). Accordingly, the products with the highest and lowest degrees of closeness were cow cheese and yogurt and ayran and drinking milk, respectively. These products are among the most produced and most demanded products. Therefore, production and purchase of cow cheese and yogurt are more important than other products. One of the reasons why ayran and drinking milk products have the lowest degree of closeness is that production is concentrated in different periods. Raw milk supply and seasonal changes in consumer preferences result in the effective production planning of these two products. Contrary to ayran production, increasing the production of UHT drinking milk, especially in the months when raw milk supply is high, is used as a production strategy to utilize the excess milk. However, this product is produced by very few companies in Turkey due to the cost of the infrastructure required for the production of UHT drinking milk. Furthermore, a central node is quickly affected by changes in any part of the network with a high degree of closeness and can quickly affect changes in other parts of the network (Borgatti, 2005). Therefore, ayran and drinking milk are not affected by the market, and their production amounts are determined in line with their internal dynamics rather than other products.

The centrality measure (Table 2) performed over numerous links revealed that yogurt had the highest degree of centrality (1,622). Ayran had the lowest value with −1.42. Yogurt with the highest degree of centrality is a major product associated with all products in the market, including other products that it has no link with.

The influence values (Table 2) show that products with the strongest influence were raw milk (1,156) and cow cheese (1,505). In other words, raw milk and cow cheese affect other products in the network. The key member in the network analysis is determined by degree centrality and betweenness centrality values (Sinha & Mihalcea, 2007). Accordingly, the key member of the market was yogurt with the highest score for both values.

A clustering coefficient measures the local group compatibility and is defined for any vertex as the fraction of connected neighbors. It reveals the strength of the link between the products and their neighbors. In other words, the sphericity coefficient can be called the statistical consistency level that measures the spherical density of the interconnected vertices in the network (Field, 2000). Considering the four different clustering coefficients, the products with the highest density were raw milk and cow cheese (Table 3). These results are consistent with the influence values listed in Table 2, and they indicate that these two products have a high influence on other products.

According to the correlation coefficients between the amounts of products produced by the dairy industry and the amount of raw milk processed, no relationship was present between raw milk and ayran and drinking milk. Accordingly, the major factor in the market supply of both products is the increase in seasonal demand and seasonal raw milk surpluses. Therefore, no relationship between the amount of raw milk and the production amount of these products was present. Ayran and yogurt had the highest correlation coefficient, with a moderate positive correlation value of 0.609 (Table 4). This value was significant for both products having similar production patterns throughout the year. Yogurt displayed a negative relationship with drinking milk, milk powder, and butter, whereas milk powder had a low, negative relationship with butter. The negative relationship between these products was due to the fact that these products were not the primary products (cheese, etc.). Therefore, the production amounts of these products may vary in relation to the demand for other products and the supply of raw milk.

In the last years of the examined period, the network of the sector changed due to the COVID-19 pandemic. Accordingly, the supply of milk and dairy products was adversely affected during the COVID-19 pandemic (Poudel et al., 2020). Examples of the problems caused by the pandemic included the closure of dairy farms that process milk and the waste of milk by producers (Weersink et al., 2020). The negative impact of the pandemic on food supply and demand may also place food security at risk (Siche, 2020). The consumption of dairy products has been reported to decrease during the pandemic (Abate et al., 2020; Hirvonen et al., 2020).

In Turkey, during the period of full and partial closure in 2019 and 2020, when the COVID-19 pandemic started, the production declined due to the demand and production in milk and dairy products, daily consumption frequency of the product, storage possibilities, and shelf-life. A related study reported that as of January 2019, a decline in the production of ayran was observed in Turkey, which further escalated after the arrival of the pandemic in April 2020. The decrease in ayran production was sharper than in other dairy products because restaurants, catering, or ready-made food companies, where ayran is consumed the most, worked at low capacity or remained closed for months during the pandemic (Akin, 2020).

The highest cost in dairy products is of the raw material (raw milk) (Akin & Cevger, 2019). In addition, the network analysis showed that raw milk acted as the determinant and was effective in the market. The volatility in milk prices leads to different effects among countries and socioeconomic groups. Increasing milk prices benefit the net exporting countries that respond quickly to new market trends, as well as producers (Acosta et al., 2014). However, raw milk prices did not increase for a long time in Turkey and the increase in production costs negatively affected the sector, especially the farmers. For the development of the sector, the emergence of farmers' boutique enterprises producing local agri-food systems style regional and geographically indicated products and the structuring of marketing channels should be seen to be catalysts for rural development, agricultural modernization, and good market accessibility of farmers (Markelova et al., 2009). For the Turkish dairy sector to have a sustainable structure, dairies and small-scale enterprises should stand out in the production of certain products, especially those with geographical indications. This is the only method to increase their competitiveness against large-scale companies with international marketing capabilities. A study stated that the primary motivation of dairy industry enterprises was still economic factors such as reducing transportation costs and heavy expenditures on marketing operations (Sellitto et al., 2018). In this context, the scattered nature of the raw milk supply areas of the industry increases the transportation costs, which negatively affects the costs. This situation is generally similar in Turkey.

In conclusion, the benefit optimization of all stakeholders in Turkey's milk and dairy product sector is a necessity for the fair and balanced growth of the sector. The resulting pattern network structure summarizes the production relations of raw milk and final products for the enterprises and policymakers in the sector, based on both consumer demands and commercial advantages and disadvantages. Network analysis can significantly contribute to the visualization and better understanding of the national and international trade of the dairy sector. Hence, revealing the temporal changes in certain periods through network analysis can significantly contribute to the managerial success of the sector stakeholders.

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