Thesis on Measuring the Production Efficiency of Dairy Production in KOOP Factory in North Cyprus by Data Envelopment Analysis

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Master of Science
in
Industrial Engineering

Eastern Mediterranean University
September 2021
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

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ABSTRACT

The purpose of the study is to evaluate the production efficiency of the Dairy Production specifically White Cheese and Hellim Production and Total Cheese Production in one of the biggest dairy factories, KOOP in North Cyprus. Data Envelopment Analysis is applied for during the 35-month period interval between 2018 and 2020 among 5 Inputs and 2 Outputs. Processed Milk Amount, Energy Cost, Production Loss, Labor Cost, Production Amount are inputs whereas Sale Costs and 1/Waste are chosen as outputs. Input-oriented BCC model has been applied. White Cheese Production is found to be more efficient than Hellim Production. Nevertheless, increasing importance of Hellim with PDO and export opportunities via Green Line would promote its Production in the next 3-year period. Seasonal effects, political decisions and pandemic period played important role in decrease in efficiency of production in certain months. The paper gives suggestions on how to support the efficient production of both cheese types by decreasing the production loss, energy costs and wastes.

Keywords: Data Envelopment Analysis, CCR Model, BCC Model, Dairy Processing, Efficiency

ÖZ

Bu tezde KKTC'nin en önemli gelir kaynaklarından biri olan Süt Sektörünün öncü işletmelerinden KOOP'un peynir üretim verimliliği araştırılmış, Beyaz Peynir, Hellim ve Toplam Peynir Üretimi 35 ay süre zarfında 5 girdi ve 2 çıktı parametreleri ışığında Veri Zarflama Analizi ile değerlendirilmiştir. İşlenen süt miktarı, Enerji Maaliyetleri, Fire, İşçi Maaliyetleri ve Üretim Miktarı girdiler olup, Satış Maaliyetleri ve 1/Atık çıktılar arasında yer almaktadır. Girdi odaklı BCC modeli kullanılmıştır. Beyaz Peynir Üretiminin Hellim Üretiminden daha verimli olduğu ortaya çıkmış olup, Hellim Tescili ile artacak olan Hellim İhracatı ve talepten dolayı verimliliği artıracak farklı yöntemler araştırılmıştır. Mevsimsel değişimler, politik gelişmeler ve pandemi şartları üretim verimliliğini azaltan ana etkenler arasındadır. Bu tez aracılığıyla KOOP Üretim Tesislerinin verimliliğini arttırmak ve ekonomik sürdürülebilirliği sağlamak adına etkin bir atık yöntemi ve üretim maliyetlerini azaltma yöntemleri uygulanacak, gelecek dönemler için ekonomik tavsiyelerde bulunulacak.

Anahtar Kelimeler: Veri Zarflama Analizi, CCR Model, BCC Model, Süt Üretim Tesisi, Verimlilik

ACKNOWLEDGEMENT

I would like to kindly show my appreciation to my supervisor Assist. Prof. Dr. Sahand Daneshvar for his continuous support and guidance in many ways throughout the study. Special thanks to Deputy Manager of KOOP Factory Quality and Production Mrs. Tuğşen Çıldam and Vice Chairman of Development Bank Mr. Nevzat Nevzat. I would like to thank to my family for the encouragement and for giving me the opportunity to make the study.

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LIST OF ABBREVIATIONS

DEA	Data Envelopment Analysis
DMU	Decision Making Unit
PDO	Protected Designation of Origin
PPS	Production Possibility Set
SUTEK	Süt Endüstrisi Kurumu
UHT	Ultra-High Temperature

Chapter 1

INTRODUCTION

One of the most important industry in North Cyprus is Dairy Industry. Back in the history, people used to process mostly sheep and goat milk at their own farms and homes. In late 50s with an increase in milk amounts in the market, couple of farmers gathered and initiated a cheese processing plant called KOOP. Increased work load in the plant, initiated an establishment called Cyprus Turkish Milk Industry Institution (SUTEK). Since then, SUTEK is responsible for gathering all milk produced by farmers, analyze, maintain standards and sell to manufacturers including KOOP. Nowadays, KOOP is the biggest milk processing plant in North Cyprus and maintaining high quality production by applying ISO:9001:2000, HACCP and ISO:22000 standards.

Dairy Products are the second most exported products after Citrus from the country. Despite the fact that KOOP is one of the most high-tech milk processing plant with high efficiency, the company sometimes face difficulties to meet demand for the foreign market. The hot climate and draught in the country causes inconsistency of feeding material which results in inconsistency in milk quality. Therefore, product quality become variable. It is a challenge to maintain the standards especially for the batches which are exported.

Another challenge in Dairy Sector is, not all farmers have cold chain milking system in their farms. This causes high somatic cell count in milk and sometimes even spoilage of milk. Low quality milk acceptance also affects product quality negatively and may be problematic as well in export products.

Specifically, Hellim is one of the most popular products and becoming more popular after the official registration of the product as Protected Designation of Origin on April, 2021. In other words, after the completion of transition period of maintaining EU Standards, the product will be able to be exported EU via Green Line Regulation. Currently, there is deficiency of sheep and goat milk in the market which is the main challenge in order to be able to export Hellim to EU. Because the product must be produced by using more than half of sheep and goat milk and nearly half of cow milk.

Since the beginning of dairy sector, there is ongoing issue of high waste of whey protein in TRNC. In cheese products, after the cheese formation high amount of whey protein is released. Due to lack of processing facilities of whey protein, it is being disposed to the closest municipality drainage as a waste. The whey protein is very precious material which could be utilized in production of many products just as milk powder as an ingredient to coffee, soups, supplements, chocolates…etc. Wasting the whey protein increases the production cost and decreases the efficiency of the factory.

In the study, Data Envelopment Analysis method is used which originated by A.Charnes, W.W.Cooper, and Rhodes (CCR Model) in 1978 and improved by Banker, R.D., and Charnes, A., & Cooper, W.W (BCC Model) in. 1984. In CCR Model there is constant returns to scale where in BCC model Returns to Scale is variable. In constant returns to scale system, input changes and output changes proportionately.

On the other hand, if output decreases more than the decrease in input, it is called Decreasing Returns to Scale and if output increases more than the increase in input it is called Increasing Returns to Scale.

In the study, BCC model is used with 5 inputs and 2 outputs for 35 DMUs between January 2018 and November 2020. Each DMUs production parameters are analyzed within each DMU and inefficient ones are compared to efficient ones. Input orientated model is used where only input variables are changed to be efficient. Input Oriented BCC Model is analyzed for Hellim, White Cheese and Total Cheese Production.

KOOP Factory has a wide range of products including, UHT Whole Milk, Low Fat milk, Skim Milk, Hellim, Low Fat Hellim, White Cheese, Cream Cheese, Edam Cheese, Kosher Cheese, Fruit Juices, Yoghurt, Ayran and Ice-cream. In this study, only 2 products; Hellim and White Cheese data are examined. Input parameters are Labor Costs, Production Loss, Energy Costs and Production Quantities. Energy Costs are assumed to include all costs related to production consisting electric, petrol and gas.

Chapter 2

LITERATURE REVIEW

2.1 DEA History

The first article back in the history related to efficiency is ‘The Measurement of Productive Efficiency’ in 1957. (Farrell, M.J., 1957). The productive efficiency was aimed to be measured by considering all inputs and computing related function. The application of the method is done in Agricultural Production in USA and aimed to be applied in wide range of sectors in industry. The first model, CCR in DEA found by Charnes, Cooper and Rhodes in 1978. The terms, Technical and Scale Efficiency were introduced. The efficiency of DMUs was measured from output/input ratios where Return to Scale assumed as constant. In other words, it is assumed that in CCR model, both inputs and outputs change by same factor to be efficient. (Charnes et al., 1978). In 1984, BCC model was initiated and an expression of Return to Scale was categorized as Increasing, Decreasing and Constant Returns to Scale where either input or output variable could be changed for or input oriented or output oriented model respectively. (Banker et al., 1984). The literature review published in 2013 has shown that the most of the applications between 1978 and 2010 on DEA were related to empirical data and the remaining to methodological data. The majority of the subjects was health care, agriculture, education, finance and the demanding sectors were environment and energy. (Liu et al., 2013)

2.2 Applications Food Industry

In Table 1, there is a list of reviewed papers in many food sectors' DEA applications including Crop, Livestock Farms, Meat, Rice, Olive Oil, Poultry, Waste and Energy Management.

Table 1: Reviewed Papers in Food Industry

Authors	**Title**	**Review**
Laure Latruffe, Kelvin Balcombe, Sophia Davidova, Katarzyna Zawalinska	Technical and scale efficiency of crop and livestock farms in Poland: does specialization matter?	In study published in 2003, technical and scale efficiency of Polish farms were measured and the efficiencies of crop and livestock farms were compared between 1996 and 2000 by using DEA method. It is found that Livestock farms are more technically efficient than Crop farms. (Latruffe et al., 2003)
Jim Taylor, Dennis Reynolds, Denise M. Brown	Multi-Factor Menu Analysis Using DEA	In order to develop Menu Analysıs Model that includes labor using labor attributes both qualitative and quantitative attributes of labor were matched with each menu in moderately priced full-service restaurant. DEA was adopted to evaluate true efficiency (Taylor et al., 2009)
Ioanna Keramidou, Angelos Mimis,Evangelia Pappa	Identifying efficiency drivers in the Greek sausage industry: a double bootstrap DEA approach	The paper investigates technical efficiency determinants for sausage industry in Greece over the period of 1994–2007. It is revealed that, there are significant factors determining the performance of the firms positively such as local sausage consumption, the background of employee and globalization potential of the firms. The size of the firm and the flexibleness affect the firm negatively. .(Keramidou et al., 2011)

AGDP Lakmal and WADN Wickramarachchi	Enhancing the Effectiveness and Efficiency of Warehouse Operations in FMCG Sector in Sri Lanka	In the paper, the efficiency of Warehouse Operations in Sri Lanka in terms of simplicity of the Warehouse Management Systems, Product slotting techniques and layout planning. The results revealed that the three factors have positive impact to the performance of each warehouse operations. It has been understood that most of the warehouses do not understand the role of adopting best practices or may not be successfully implemented in order to increase the level of productivity. (AGDP et al.,2011)
Agnieszka M. Dadura, Tzong-Ru (Jiun-Shen) Lee	Measuring the innovation ability of Taiwan's food industry using DEA	The paper aims to study originality of Taiwan's food industry and its determinants by making a questionnaire. The most and the least original samples were revealed by DEA New actions to be taken for improved originality were suggested. The determinants for originality in the paper could be applied to other food sectors and could be benchmarked and referenced in other countries. New procedures were suggested for innovativeness development by considering the company size. Agnieszka et al., 2011)
M. Omid a, F. Ghojabeige a, M. Delshad , H. Ahmadi	Energy use pattern and benchmarking of selected greenhouses in Iran using data envelopment analysis	The present paper studies the efficiency of specific cucumber produced greenhouses in Iran where they did the process of benchmarking energy inputs and cucumber yield among 18 greenhouses. The DEA was applied based on energy inputs; human labor, diesel, machinery, fertilizers, chemicals, water for irrigation, seeds and electricity and output yield values of cucumber. The study has found out that 8, 5 % of resources could be saved by increasing the performance of DMUs. The paper is the first application of DEA in greenhouse production. (Omid et al., 2011)

Homa Hosseinzadeh-Bandbafha, Dariush Safarzadeh, Ebrahim Ahmadi, Ashkan Nabavi-Pelesaraei(2016)	Optimization of energy consumption of dairy farms using data envelopment analysis – A case study: Qazvin city of Iran	The aim of this study was to use two approaches of data envelopment analysis; returns to scale and variable returns to scale were used for determining the energy efficiency and find the optimum energy consumption in dairy farms of Qazvin city of Iran. It is calculated that energy saving target ratio is 12% for dairy farms. The majority of the total saving energy is from feed intake and just over 10% is from fossil fuels. Enteric fermentation has high tendency to reduce the GHG emissions which directly related to feed intake
Hezekiah ., Lalitha Ramakhrishnan, Majid Shaban Bhat (2016)	Advertising Media Efficiency of FMCG Firms in India: An Empirical Investigation Using Data Envelopment Analysis	The article is aimed to study advertisement expenses of a group of FMCG companies between years 2006 and 2012. DEA is used and efficiency is evaluated by measuring Overall, Pure and Scale Efficiencies of each company in specific years. It has found out that OTE shows 6% of the companies is efficient whereas PTE shows 22% is efficient in advertisement costs. It is also resulted that the companies must decrease their inputs by half for an increased efficiency. (Hezekiah., 2016)
Kiyotaka Masuda(2018)	Energy Efficiency of Intensive Rice Production in Japan: An Application of Data Envelopment Analysis	In the paper, the energy efficiency of increased rice production in Japan is studied. DEA is used and Window Analysis Method is applied to various size farms between 2005 and 2011. Inputs were energy originated expenses and output was rice yield. It resulted as increasing the scale of rice farming in Japan, energy efficiency increases because energy consumed per unit area by agricultural machinery and agricultural services decreases.
Jinyan Zhan, Fan Zhang, Zhihui Li, Yue Zhang, Wei Qi (2018)	Evaluation of food security based on DEA method: a case study of Heihe River Basin	In this article, agricultural productivity of 11 countries in Heihe River Basin was analyzed between 1990-2012 by DEA. Input parameters were sown area, agriculture, farm labor, general agricultural machine power and fertilizer where output was gross agricultural production. It is shown that the production was not balanced between the periods where scale efficiency remained same.

Sylwester Kozak, Karolina Kossowska(2018)	Changes In The Level Of Technical And Scale Efficiency Of The Food Sector Enterprises In Poland In The Years 2006–2016	This article studies the efficiency of 51 Polish food producers between years 2006–2016. DEA method was used to measure Technical and scale efficiency. It was shown that technical efficiency of enterprises ranged from 82 to 93%. Most of companies characterized with the high efficiency and increasing return to scale. Companies characterized with high scale efficiency at the interval of 87–93% throughout the entire period.
Anthony N. Rezitis, Anthony N. Rezitis (2015)	Investigating Technical Efficiency and Its Determinants by Data Envelopment Analysis: An Application in the Greek Food and Beverages Manufacturing Industry	In this paper, Tobit and the OLS regressions were applied in order to investigate technical efficiency and its determinants in the Greek food and beverages manufacturing industry for the period 1984–2007. It has showed that the most important parameters were sector size, capital productivity, labor productivity, and labor intensity. The results also showed that during the period 1984–2007, the technical efficiency of the whole industry tended to decrease. Additionally, the present paper provides some policy recommendations that could enlighten the present economic crisis.
Edward Kasem1, Oldřich Trenz1, Jiří Hřebíček1, Oldřich Faldík(2015)	Key Sustainability Performance Indicator Analysis For Czech Breweries	In this article, the efficiency of Czech breweries was evaluated. DEA was applied by using KPI. Sustainability performance is measured within different aspects such as economic, environmental, and social and governance. According to the achieved efficiency results for Czech breweries, the percentage of women supervising the company does not affect the sustainability performance.
Rafaela Dios-Palomares a, José M. Martínez-Paz(2011)	Technical, quality and environmental efficiency of the olive oil industry	This paper studies the level of technical efficiency in accordance with production and quality and environmental management in the olive oil industry in Spain by DEA technique. It is revealed that the firms with higher efficiency is the ones who have better management of inputs in compliance with quality and environmental levels. It is also found that, firms registered as cooperatives have lower efficiencies due to poor education of employee.

		The firms with less efficiency are recommended to have more planning and optimization in raw material supply and production procedures. Another conclusion has been drawn: more efficient firms are those with higher training levels.
Diego Iribarren, Almudena Hospido, María Teresa Moreira, Gumersindo Feijoo (2011)	Benchmarking environmental and operational parameters through eco-efficiency criteria for dairy farms	This article shows the joint implementation of LCA and Data Envelopment Analysis (DEA) in order to avoid the formulation of an average farm, while obtaining the characterization and benchmarking of the operational and environmental performance of total 72 dairy farms in Spain. The combined analyses were applied to eliminate inefficient operations and to optimize the input values for increased eco-efficiency. The results showed that 20% decrease in environmental impact could be reached by decreasing 38% of inputs. Increased efficiency would end up with increased savings where up to 40 % extra profit was estimated.
Jorge Cristóbal, Phantisa Limleamthongb, Simone Manfredia, Gonzalo Guillén-Gosálbezc(2016)	Methodology for combined use of data envelopment analysis and life cycle assessment applied to food waste management	The paper studies on combination of DEA and LCA (Life Cycle Assessment) methods in order to minimize food waste by technological management techniques. For example, it starts by assessing the management options with respect to 12 environmental indicators (recommended in the European Commission Product Environmental Footprint method). First of all, DEA is applied to differentiate inefficient options from efficient ones and later it is worked on how to improve the inefficient options. In total, 6 management options were studied and results show that more than half of the options were efficient, while the rest were considered inefficient.

Jara Laso, Daniel Hoehn, María Margallo, Isabel García-Herrero , Laura Batlle-Bayer, Alba Bala ,Pere Fullana-i-Palmer , Ian Vázquez-Rowe , Angel Irabien and Rubén Aldaco	Assessing Energy and Environmental Efficiency of the Spanish Agro-Food System Using the LCA/DEA Methodology	This paper is focused on measuring the efficiency of Spanish agro-food system to decrease energy use and GHG emissions by applying LCA and DEA. It was found that 70 % of the system was energy efficient and DEA was found as very useful tool to identy the efficient and inefficient systems. (2018)
Lena Kuhn, Tomas Balezentis, Lingling Hou, Dan Wang	Technical and environmental efficiency of livestock farms in China: a slacks-based DEA approach	In the paper, technical and environmental efficiency of 371 Chinese hog farms were evaluated by DEA. It is found that medium size farms were less efficient due to restricted waste disposal opportunities. The government policies lack in support for improved waste management. Therefore, specifically small farms have lower efficiencies and requires more support. (2018)
Ricardo Rebolledo-Leiva , Lidia Angulo-Meza , Alfredo Iriarte , Marcela C. González-Araya (2017)	Joint carbon footprint assessment and data envelopment analysis for the reduction of greenhouse gas emissions in agriculture production	In this paper, eco-efficiency of blueberry orchards was studied by aiming to decrease environmental impact such as Carbon Footprint, by using less resources and by increasing production. Output oriented DEA is applied and both ecological and economic efficiency of 5 blueberry orchards were measured in 3 seasons. The results show that this method is a good tool to evaluate eco-efficiency and to reduce GHG emissions. (2017)

Murilo Pagotto and Anthony Halog (2015)	Towards a Circular Economy in Australian Agri-food Industry	The paper is aimed to evaluate the efficiency of Agro-food Industry in Australia by DEA and Material Flow Analysis. The outcomes showed the inefficiencies in production process. It is recommended to minimize outputs and to promote use of renewable inputs to increase efficiency. As a result, it is suggested to move to a circular production system for an increased sustainability and efficiency. (2015)
Christos T. Papadas, Dale C. Dahl (1991)	Technical Efficiency And Farm Size: A Non-Parametric Frontier Analysis	A study was revealed in 1991, investigating the relation between technical efficiency and the size of firms according to sales classes. DEA was applied with seven inputs related to production expenditures and 2 outputs related to sales. It had been revealed that the efficiency decreases from large to medium farms and then started to increase when the size of the firm becomes smaller. This related to decreased farm labor in small farms especially the family farms who relies on family labor are more efficient. (Papadas., Dahl., 1991)
Sama Amid , Tarahom Mesri Gundoshmian, Gholamhossein Shahgoli, Shahin Rafiee	Energy use pattern and optimization of energy required for broiler production using data envelopment analysis	This paper published in 2016 studied energy consumption of broiler production in Ardabil province of Iran where DEA was used to analyze energy efficiency, separate efficient from inefficient broiler producers, and calculate wasteful use of energy to optimize energy among 70 broiler farmers. The DEA results revealed that 40% and 22.86% of total units were efficient based on the CCR and BCC models, respectively. It is found that, fuel consumption is 72 % of the total energy consumption and the rest is feed and electricity consumption. It shows that there is good opportunity to increase savings by following recommendations for efficient energy use. (Amid et al., 2016)

Matthew Gorton , Sophia Davidova	Farm productivity and efficiency in the CEE applicant countries: a synthesis of results	The study published in 2002, gathered results from studies concerning farm efficiencies in 6 different Central and East European countries in EU enlargement process. The aim was to compare the efficiency of family farms and corporate farms and find relation between size and farm efficiency of a specific farm. It is found out that well managed, experienced small firms are more efficient than large corporates. When the types of the farms were compared (family vs. corporate) there is no clear evidence that corporate farms are less efficient than family farms however significant differences have been found in favor of family farms against the average corporate farm. (Gorton & Davidova, 2004)
Mohammad Davoud Heidari, Mahmoud Omid, Asadollah Akram (2011)	Optimization of Energy Consumption of Broiler Production Farms	This study published in 2011 applied DEA to identify efficient farms among 44 broiler farms in Yazd Province in Iran. The purpose was to minimize the unnecessary use of energy in production. Two basic DEA models (CCR and BCC) were applied and 10 and 16 farmers were found to be efficient respectively. It is found that 11% of inputs could be saved when the input package recommendations were applied. (Heidari et al., 2011)
Ismat Ara Begum, Mohammad Jahangir Alam, Jeroen Buysse, Aymen Frija Guido Van Huylenbroeck (2012)	Contract Farmer and Poultry Farm Efficiency in Bangladesh: A Data Envelopment Analysis	The study published in 2011 and is unique study focused on poultry farm in Bangladesh. DEA approach under CRS and VRS specification is applied on independent and contract poultry farms. It has found out that technical, allocative and economic efficiencies of contract farms are higher than independent farms. Tobit model used **(**(Begum et al., 2012)

Todsadee Areerat, Kameyama Hiroshi, Ngamsomsuk Kamol, Yamauchi Koh-en (2012)	Economic Efficiency of Broiler Farms in Thailand: Data Envelopment Analysis Approach	The objective of this study was to determine the efficiency of broiler farm in Chiang Mai province of Thailand. DEA approach; CCR and VRS models applied. According to CCR only 1 farm was found to be efficient whereas VRS showed 3 farmers to be efficient Tobit model has been used. In CRS model, the size of the farm and the background of the farmer were the factors affecting the efficiency whereas in VRS model, experience of the farmer was inversely proportional to the efficiency of the farm.
Paria Sefeedpari, Shahin Rafiee, Asadollah Akram (2013)	Identifying sustainable and efficient poultry farms in the light of energy use efficiency: a Data Envelopment Analysis approach	The study published in 2013 focusses on 44 poultry farms where egg production is in place. The main purpose is to differentiate the efficient and inefficient farmers according to optimal energy load of inputs such as human labor, equipment, fossil fuel, electricity, feed supply and egg yield as an output. Based on the findings, fossil fuel and electricity were determined as the most inefficient inputs. The results also revealed that about 22% of the total input resources could be saved if the farmers follow the input package recommended by the DEA. Based on the results, promoting the inefficient farmers' level of knowledge, applying more high-tech equipment and taking advantage of renewable energy sources would increase the efficiency and increase sustainability. (Sefeedpari et al., 2013)
Omar, M. A. E. (2014)	Technical and economic efficiency for broiler farms in Egypt. Application of data envelopment analysis (DEA).	In this paper, the efficiency of 50 broiler farms in 3 different provinces in Egypt was evaluated by DEA and SPSS. It is found that large farms over 10,000 birds were more efficient than small farms with less than 5000 birds. Farms having up to 5000 birds were classified as small, those with 5000-10000 birds as medium and those over 10000 birds as large. The main reason was found to be better management techniques, improved feeding programs and veterinary services which provide better cost management and increase profits.

M.S. Sadiq, I.P. Singh and M. Lawal (2019)	Identifying Sustainable and Efficient Broiler Farms in the Light of Energy Use Efficiency and GHG Emission Reduction: Data Envelopment Analysis Approach	Addition to previously published papers, the paper published in 2019 studied on identifying both energy efficiency and GHG emission to maintain sustainability of the total 55 broiler farms in Nigeria. The results showed that 63% of farms were efficient in terms of technical efficiency whereas nearly 80% was found efficient under pure technical efficiency. Further, 1.38% of overall input energies can be saved if the performance of inefficient farms rose to a high level. The study concludes that the total GHG emission can be reduced to the value of 981.08 Kg CO2eq by energy optimization. (Sadiq et al., 2019)

2.3 Applications in Dairy Industry

The reviewed papers on DEA Applications in Dairy Farms and Cheese Processing Plants are listed in Table 2. The most of the articles have focused on regional or country-based benchmarking.

Table2: Reviewed Papers in Dairy Industry

Authors	**Title**	**Review**
I. Fraser *, D. Cordina (1999)	An application of data envelopment analysis to irrigated dairy farms in Northern Victoria, Australia	In this paper, efficiency of dairy farms were evaluated by DEA and found that a considerable amount of farms are efficient. It has been found that there exists a potential 16% reduction in water use if all farms operated efficiently. It is suggested that this reduction in water use will compensate for the proposed reductions in available water. Alternatively, output could be increased on average per annum by 6000 kg yielding around $37,000 extra revenue. There is significant difference

		between efficient farms and inefficient ones however further research is required for investigating the real reason behind. (Fraser & Cordina, 1999)
Tengfang Xu*, Joris Flapper, Klaas Jan Kramer(2009)	Characterization of energy use and performance of global cheese processing	In this study, it is found that the final energy intensity of some cheese processing plants ranges from 1.8 and 68.2 MJ per kg of cheese between countries. There is large potential for energy savings in the sector due to the wide range. It is also found that there is positive relation between energy precautions and decreasing energy consumption over time. Therefore, it is suggested that energy-benchmarking framework for evaluating energy performance and improving the energy efficiency could be developed. (Xu et al., 2009)
Paria Sefeedpari a, * , Zeinab Shokoohi b, **, Seyyed Hassan Pishgar-Komleh (2020)	Dynamic energy efficiency assessment of dairy farming system in Iran: Application of window data envelopment analysis	The average efficiency score of Iranian dairy farming production system was estimated at approximately 0.85 and It is found that three provinces including Zanjan, Ardabil and Hormozgan had the highest technical efficiencies. Window analysis is used to evaluate technical efficiencies and energy consumption over the years. The difference in milk production capacities is a

		considerable amount. The provinces with higher milk capacity are found to be less efficient. The technical efficiency of dairy farming in Iran could be increased by improving resource use efficiency to optimize energy consumption (Sefeedpari et al., 2020)
Reza Kiani Mavi1 and Craig Standing	Eco-Innovation Analysis With DEA: An Application To OECD Countries	This paper investigated eco-innovation of OECD countries using data envelopment analysis. It is found that Switzerland, Ireland, Iceland and Luxembourg are eco-innovative and other countries must sample these countries. DEA results were evaluated output oriented.
Jin Ee Mo, Zi Yi Mok*, Slyvia Moh Sze Tan, Dariush Khezrimotlagh (2014)	Measuring the Efficiency of the Dairy Industry: Using DEA Models	The paper is focused on measuring efficiency of milk 23 processing plants by DEA in US. A model called KAM is applied with 8 inputs and 4 outputs. It is found that 20 of the plants are efficient when there is Constant Return to Scale. (2014)
Finn R. Førsund and Lennart Hjalmarsson(1979)	Generalized Farrell Measures of Efficiency: An Application to Milk Processing in Swedish Dairy Plants	The study is focused on 28 different dairy plants who produce homogenized and pasteurized milk. Different results were revealed from technical and scale efficiency values. This was due to the modernity of equipment and differences in management.

Chapter 3

METHODOLOGY

3.1 Model

Data Envelopment Analysis is a method used to evaluate performance for multiple input and multiple output system and by providing benchmarking both within a company itself and others in the sector. In the first DEA model, CCR, which initiated by Charnes, Cooper and Rhodes (1978), returns to scale assumed as constant where output changes with a factor, input also changes with the same factor. Decision Making Unit, DMU is the function of producing outputs from inputs. (Tone, 2007). And all production functions are located in Production Possibility Set, PPS.

On the other hand, in BCC model developed by Banker, Charnes and Cooper (1984) Return to Scale is variable. Additionally, the model could be output oriented when input values kept constant and output is variable and the model is input oriented when output value is kept constant while input is changing within PPS. In the thesis, input oriented BCC model is used.

The production possibility set, PPS ;

1. PPS is a set of functions of (X_j, Y_j)

Where $j = 1,...,n$ ∈ PPS

c :inputs, b : outputs

2. When (X, Y) is in PPS , t ≥ 0, (tX , tY) ∈ PPS , Constant Returns to Scale.

3. (X_j , Y_j) ∈ PPS

(X , Y_j) ∈ PPS where X > X_j

(X_j , Y) ∈ PPS where Y < Y_j

4. Any positive linear combination of functions in PPS are also in PPS .

5. λ is a linear vector in R^n .

$X = (x_j)$ and $Y = (y_j)$

$$PPS = \{(X,Y) \mid X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, \sum_{j=1}^{n} \lambda_j = 1, \lambda_j \geq 0, j = 1,2,...,n\} \qquad (3.1)$$

6. $X_j \geq 0, X_j \neq 0, x \in R^c, j = 1,2,...,n$
$Y_j \geq 0, Y_j \neq 0, y \in R^b, j = 1,2,...,n$

The primal form of BCC model;

Envelopment side:

$$Min\theta_z \qquad (3.2)$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}.\lambda_j \leq \theta z.x_{jz} \qquad i = 1,2,...,m ; \qquad (3.3)$$

$$\sum_{j=1}^{n} y_{rj}.\lambda_j \leq \theta z.y_{rz} \qquad r = 1,2,...,s ; \qquad (3.4)$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad (3.5)$$

$$\lambda_j \geq 0, \forall_{i,j,r} \qquad (3.6)$$

z= the DMU being evaluated in the set of j= 1, 2… n DMUs

θ_z = the measure of efficiency of DMU z, the DMU in the set of j= 1, 2…, n

y_{rz} = the amount of output b produced by DMU z

x_{iz} = the amount of resource input i used by DMU z

y_{rj} = the amount of service output r produced by DMU j

x_{ij} = the amount of service input i used by DMU j

u_{rz} = the weight assigned to service output r computed in the solution of the DEA model

v_{iz} = the weight assigned to resource input i computed in the solution of the DEA model

c= number of inputs used by the DMUs

b= number of outputs produced by the DMUs

The dual form of BCC model;

Multiplier side

$$Max\sum_{r=1}^{b} u_{rz}.y_{rz} + u_0 \qquad (3.7)$$

Subject to:

$$\sum_{i=1}^{c} v_{iz}.x_{iz} = 1 \qquad (3.8)$$

$$\sum_{r=1}^{b} u_{rz}.v_{rj} - \sum_{i=1}^{m} v_{iz}.x_{ij} + u_0 \leq 0 \quad \text{j = 1,2,...,n} \qquad (3.9)$$

$u_{rz}, v_{iz} \geq 0,$ r = 1,2,...b; i = 1,2,...,c

3.2 Data Collection

The data collected between the years 2018 and 2020 for White cheese Production, Hellim Production and Total Cheese Production in the KOOP Factory. There are 35 Decision Making Units in total starting from January 2018 till November 2020. Data used in DEA consists of 5 inputs and 2 outputs. Inputs are Processed Milk Amount, Labor Costs, Loss, Electric Costs and Production Amount. Outputs consist of Sales and Waste.

Table3: Defining the variables

		Unit:	**Definition:**
Input 1	Processed Milk Amount	Tons	Entering amount of milk to be processed to be cheese
Input 2	Labor Costs	Turkish Lira	Total Labor Costs including Production and Administration Staff involved in Production both directly and indirectly.
Input 3	Loss	Percentage %	Percentage of Final or Semi-Finished Product wasted during production.
Input 4	Energy Costs	Turkish Lira	All fuel/ energy costs consumed during Production.
Input 5	Production Amount	Tons	Production Amount of Cheese in Tones
Output 1	Sales	Turkish Lira	Total Sales Income of Produced Cheese in TL

Output 2	Waste	Tons	Amount of Whey Protein Wasted during Cheese Production

Each cheese type has different yield. Monthly processed milk amount calculated from the different yields of cheese types. For example 1 kg of White Cheese is produced from nearly 6 kg of milk whereas 1 kg of Hellim is produced from 8 kg of milk. The exact Milk Amounts calculated according to monthly given proportion data from the Production Department of the company. Administration staff costs and production staff costs are taken from Human Resources Department. They are summed up under the labor costs column. Production amount, Loss, Energy Cost and Waste Data are taken from Production Department. It is assumed that all energy consumption related to production is included into Energy Costs. Sales data is taken from the Sales Department. Since whey protein the most important waste in dairy processing industry, it has been chosen as an output and calculated as 1/whey protein and normalized. By applying DEA method, the outputs are aimed to be increased. All data has been normalized as seen in Table 4.

Table 4: Normalized Raw Data

DMU	Input 1	Input 2	Input 3	Input 4	Input 5	Output 1	Output 2
1	0,58	0,28	0,50	0,17	0,58	0,40	1,00
2	0,70	0,28	0,73	0,25	0,70	0,45	0,94
3	0,61	0,28	1,00	0,19	0,61	0,28	0,88
4	0,76	0,28	0,83	0,37	0,76	0,62	0,75
5	0,78	0,33	0,60	0,45	0,78	0,40	0,75
6	0,37	0,28	0,77	0,22	0,37	0,39	0,75
7	0,44	0,36	0,97	0,24	0,44	0,29	0,75
8	0,52	0,31	0,90	0,40	0,52	0,33	0,75
9	0,52	0,31	0,57	0,43	0,52	0,49	0,75
10	0,58	0,31	0,63	0,36	0,58	0,29	0,75
11	0,70	0,31	0,73	0,45	0,70	0,71	0,60
12	0,54	0,75	0,70	0,29	0,54	0,51	0,56
13	0,95	0,38	0,87	0,52	0,95	0,46	0,50
14	0,96	0,38	0,53	0,59	0,96	0,46	0,47
15	0,95	0,38	0,87	0,52	0,95	0,71	0,47
16	0,60	0,38	0,77	0,41	0,60	0,60	0,47
17	0,54	0,44	0,37	0,55	0,54	0,79	0,47
18	0,59	0,39	0,53	0,64	0,59	0,54	0,47
19	0,69	0,47	0,93	0,89	0,69	0,49	0,47
20	0,29	0,40	0,93	0,39	0,29	0,45	0,47
21	0,40	0,41	0,67	0,51	0,40	0,49	0,45
22	0,47	0,41	0,47	0,52	0,47	0,40	0,43
23	0,48	0,44	0,50	0,48	0,48	0,47	0,43
24	0,75	1,00	0,57	0,68	0,75	0,56	0,43
25	0,83	0,44	0,77	0,58	0,83	0,90	0,41
26	0,91	0,44	0,43	0,62	0,91	0,81	0,38
27	0,90	0,44	0,83	0,64	0,90	0,55	0,37
28	0,85	0,44	0,93	0,68	0,85	0,54	0,37
29	1,00	0,49	0,90	0,76	1,00	0,61	0,36
30	0,78	0,48	0,33	0,73	0,78	1,00	0,36
31	0,68	0,60	0,43	1,00	0,68	0,68	0,36
32	0,47	0,50	0,80	0,55	0,47	0,58	0,33
33	0,46	0,48	0,53	0,73	0,46	0,47	0,32
34	0,42	0,50	0,90	0,36	0,42	0,39	0,32
35	0,32	0,52	0,97	0,26	0,32	0,61	0,32

3.2.1 Limitations

Due to the lack of data related to energy consumption of production, production related electric cost is assumed as total energy cost. In reality, there would be higher energy costs, when the transportation and other means of energy consumption related to production are summed up. Additionally, due to the complexity of data, inflation rate assumed to be unchanged during the period of study between 2018 and 2020.

Chapter 4

RESULTS

4.1 DEA Results for Hellim Production

As seen in Table 5, Hellim Production is found to be efficient in every 5-6 months which correspond to the New Year period and the beginning of the summer for the most of the times. The increasing sales during New Year increase the production efficiency. End spring period is the period where there is maximum availability of green fodder where the milk yield reaches peak and the weather conditions are convenient for animal welfare. This provides higher milk yield followed by higher Hellim production yield. The Hellim production efficiency found to be lowest at DMU 19, July, 2019. The reason behind is the new decision taken by local authorities in March 2019. They have decided that, farmers who do not have cold chain in their farms would no longer be able to sell their milk to SUTEK unless they switch to cold or cooled system. This caused chaos and affected milk yield and product yield negatively. The efficiency of Hellim Production was also very low in the first half of 2020 between DMU 26 and DMU 29. This was because of the Covid 19 outbreak in TRNC where everywhere had to shut except for food production plants and some other vital sectors like supermarkets, petrol stations, hospitals and pharmacies.

Table 5: Efficiency for Hellim Production

Name	Efficiency	Name	Efficiency
DMU01	100	DMU19	67,24
DMU02	99,97	DMU20	100
DMU03	99,54	DMU21	100
DMU04	100	DMU22	100
DMU05	85,48	DMU23	98,47
DMU06	100	DMU24	71,65
DMU07	88,19	DMU25	100
DMU08	88,98	DMU26	94,54
DMU09	99,52	DMU27	69,83
DMU10	89,65	DMU28	68,9
DMU11	100	DMU29	65,21
DMU12	89,25	DMU30	100
DMU13	73,13	DMU31	83,79
DMU14	86,2	DMU32	84,85
DMU15	85,87	DMU33	98,8
DMU16	89,6	DMU34	85,4
DMU17	100	DMU35	100

In Lambda Table for Hellim Production in Appendix A, It is seen that DMUs with 100% efficiency has different lambda values which would be used as a parameter for inefficient DMUs to be efficient. As it can be seen, the most referenced DMUs are 1, 6, 17, 11 and 22. The factory performs 100% efficient production once in every 10-11 months and the period generally corresponds to winter season. Availability of high quality of milk in the market in winter season affects production efficiency significantly. If the parameters applied in efficient DMUs were applied to inefficient ones, such as increased milk yield and increased processing capacity with less production cost, the production efficiency would have increased.

The importance of production parameters are ranked according to their performance to increase the efficiency. As it can be seen in Weight Table for Hellim Production in

Appendix A, Hellim production efficiency is very dependent on labor costs, processed milk amount and sales. Labor costs have the highest ranking. Since Hellim production consists of many steps such as pasteurization, fermentation, cutting, pressing, cooking, draining and brining it requires high labor so labor cost is one of the highest costs in production. Additionally, as expected, increasing the processed milk amount would increase the production and sales. The DEA results are compatible with the reality.

Target Table for Hellim Production in Appendix A.3 where targeted decrease for each input parameter is shown as a percentage in order to reach 100% efficiency. The highest percentage of decrease is targeted in Production Amounts, Index 5 and Energy Costs, Index 4. The most effective change could be done specifically in pandemic period for increased efficiency in production. Hellim production capacity is targeted to decrease by 20%.

In Cross efficiency for Hellim Production Table A.4 in Appendix A, it is shown that DMU 1, DMU 6 and DMU 17 are the months which have specific production parameters which would have increase half or more than half of the DMUs efficiency when applied. The common parameter in DMU 1 and 17 is the minimum production loss when compared to other DMUs. Furthermore, the processed amount of milk is minimum for DMU 6. For Hellim Production, since the production process is stepwise complicated and more costly, decreasing the production capacity increase the efficiency. However, considering the market demand it is not very applicable in real life.

4.2 DEA Results for White Cheese Production

As seen in Table 6, 2018 was very efficient year in terms of White Cheese Production except for DMU5, DMU 7 and DMU 10. Beginning months of summer in 2018 and beginning of autumn in 2018 was inefficient. This could be due to transition in climate when between spring to summer and from summer to autumn season. It is also seen that, the white cheese production has the least efficiency in December, 2019. When the production parameters are observed, it is observed that labor costs are very high due to bonuses paid annually to employee. In 2019, DMU 15,16,20,21 and 23 were found to be 100% efficient. Similar to 2018, same months were found to 100% efficient. In spring and autumn, due to climate conditions and improved animal welfare milk yield increases and affect the product efficiency. In 2019, the negative effects of pandemic reflected as low production efficiency.

Table 6: Efficiency Table for White Cheese Production

Name	Efficiency	Name	Efficiency
DMU01	100		
DMU02	100	DMU19	89,74
DMU03	100	DMU20	100
DMU04	100	DMU21	100
DMU05	92,72	DMU22	77,16
DMU06	100	DMU23	100
DMU07	81,18	DMU24	57,63
DMU08	100	DMU25	71,95
DMU09	100	DMU26	74,66
DMU10	99,25	DMU27	86,11
DMU11	100	DMU28	100
DMU12	100	DMU29	84,62
DMU13	84,45	DMU30	84,47
DMU14	79,52	DMU31	73,01
DMU15	100	DMU32	75,85
DMU16	100	DMU33	100
DMU17	79,54	DMU34	72,04
DMU18	94,88	DMU35	87,79

Similar to Hellim Production, White Cheese Production efficiency is very dependent on Input 2; Labor Costs as seen in Appendix B.1 however when compared to Hellim Production It has lower weight. Output 1, The Amount of Produced Cheese is the second most important parameter determining production efficiency of White Cheese Production followed by Input 4 and Input 3, Energy Loss and Production Loss respectively. Due to market demand, the production capacity of white cheese is much lower than the production capacity of Hellim Cheese. Therefore, production capacity has a great role on production efficiency. As production capacity increases, sales increase and white cheese production efficiency increases.

In Lambda Table for White Cheese Production in Appendix B.2, DMU 1, 9, 11 and 20 were referenced the most for White Cheese Production. When raw data is examined for the specific DMUs, it is seen that in DMU1, production capacity was low therefore low production cost increase the efficiency. In DMU9, DMU11 and DMU 20 the sales amount is high. However, in DMU 20, despite the production capacity is low, sales amount is high because inventory products sales increased the income significantly. In DMU9 and DMU 11 the sales might have gone up due to the start of school and the upcoming of New Year.

In Target Table for White Cheese Production in Appendix B.3, the most significant parameters which are required to decrease mostly are processed amount of milk and produced amount of cheese. The production costs such as labor cost, production loss and energy costs are also targeted to be decreased but with a less extend. When considering the inefficient DMUs, labor cost must be decreased much more that the other losses in order to reach efficiency. Similar to Hellim Production, White Cheese Production would have been more efficient when the production capacity would have decreased by half.

In Total Cross Efficiency Table for White Cheese Production in Appendix B.4, the efficiency of each DMU has been calculated when the efficient DMU's production parameters are applied to inefficient ones in white cheese production. A horizontal line of the table consists of the 100% efficient DMUs in White Cheese Production. The outcomes are very similar to the outcomes from Lambda table of White Cheese Production. DMU 1, DMU 9, DMU 11 and DMU 20 are the 100 % efficient months. When the operating parameters of DMU 9 (September, 2018) and DMU 20 (August, 2019) are applied to the rest of the DMUs, more than half of DMUs became 100%

efficient. When the operating parameters of the DMUs have been checked, it can be seen that sales quantities are high despite the low production capacity. In other words, the company has sold the inventory products. On the other hand, when the production parameters of DMU 1(January, 2018) and DMU 11 (November, 201 [illegible] applied, nearly one third of DMUs became 100% efficient. In January 2018, the data shows that, production quantity of white cheese production was at maximum when compared to other DMUs. DMU 6 (June, 2018) and DMU 16 (April, 2018) are also the efficient months however the parameters are only working well for their specific month not for the rest of the months.

4.3 DEA Results for Total Cheese Production

The efficiency table below shows the efficiency levels of DMUs in Total Cheese Production. As it can been seen in Table 7, the company is generally efficient except for some months. The company has lower efficiency in summer months. The efficiency decreased between July and September 2018 followed by decrease between June and August, 2019 and so on. The reason is mainly; hot climates affect cow's milk yield negatively. Cows tend to consume more water and lack of green fodder consumption in summer season causes decrease in milk yield. Additionally, in summer months due to the hot climate, more energy is required to maintain cold chain which results in higher energy costs. After February 2020, there is significant decrease in efficiency till November 2020. The decrease occurred parallel to Covid-19 outbreak in TRNC. The negative effects of lockdown in March 2020 till May 2020 can be seen on the company sales and efficiency. During the pandemic, factories did not shut down and the farmers had continued to supply milk. However too many sectors were closed and production had to continue under restricted circumstances. The Table 15 below is the comparison of efficiencies of Total Cheese, Hellim and White Cheese Productions.

Table 7: Efficiencies of Total Cheese, Hellim and White Cheese Productions

Name	**Efficiency**		
	Total	Hellim	White Cheese
DMU01	100	100	100
DMU02	100	99,97	100
DMU03	100	99,54	100
DMU04	100	100	100
DMU05	99,59	85,48	92,72
DMU06	100	100	100
DMU07	98,73	88,19	81,18
DMU08	99,82	88,98	100
DMU09	98,74	99,52	100
DMU10	100	89,65	99,25
DMU11	100	100	100
DMU12	100	89,25	100
DMU13	98,44	73,13	84,45
DMU14	98,59	86,2	79,52
DMU15	100	85,87	100
DMU16	99,23	89,6	100
DMU17	100	100	79,54
DMU18	98,46	90,4	94,88
DMU19	98,52	67,24	89,74
DMU20	98,86	100	100
DMU21	100	100	100
DMU22	99,11	100	77,16

DMU23	98,48	98,47	100
DMU24	98,64	71,65	57,63
DMU25	100	100	71,95
DMU26	83,57	94,54	74,66
DMU27	83,86	69,83	86,11
DMU28	90,91	68,9	100
DMU29	85,34	65,21	84,62
DMU30	88,36	100	84,47
DMU31	85,6	83,79	73,01
DMU32	100	84,85	75,85
DMU33	86,41	98,8	100
DMU34	83,21	85,4	72,04
DMU35	94,69	100	87,79

As shown on Table 7, when the efficiency of each type of cheese is compared to total efficiency, white cheese has been efficient on more months than Hellim. Therefore, it has more contribution to overall efficiency of the factory on total cheese production. The main reason behind is white cheese has higher yield than Hellim. Additionally, making Hellim requires more steps and labor than making white cheese. Despite the challenges, there is more demand on Hellim in the market which makes it inevitable to decrease the production capacity.

In Appendix C.1, total lambda values of Total Cheese Production data are shown. Lambda Table is reference set table where lambda of each DMU is given as a factor to reach 100% efficiency. In other words, All DMUs are listed with different lambdas in order to be efficient like reference DMUs which are DMU 1, 2, 3, 4, 6, 10, 11, 12, 15, 7, 21, 25, 32. DMU 12 has been reference to 20 DMUs followed by reference DMU1 with 17 inefficient DMUs and reference DMU 10 with 13 inefficient DMUs whereas DMU 15 has been reference to only 3 inefficient DMUs. The reason DMU 12 and DMU 1 has been referenced the most is it is the period of New Year and the beginning of the winter. In TRNC the highest milk yield is obtained during the winter season where there is plenty of feeding material in the environment. Additionally, during the period the increase in sales have been observed due to both New Year celebrations and additional salary of government officials and bonus of private sector employee in the country. DMU10 corresponds to October, 2018, which has been seen as the 3rd most referenced month. Since the summer seasons are being very dry and hot in TRNC, end of summer increases the efficiency by increase in animal welfare, milk yield and higher motivation for employee. Furthermore, most of the employee with children use their annual leave in summer time where production has to continue with less employee. End of summer time and starting of schools correspond to this period where factory does production with full efficiency. DMU7, 8, 9 (between July 2018 and September 2018) and DMU 18, 19 (between June, 2019-July, 2019) were both referenced by DMU1, 10 and 12. If it is assumed that both periods are in a summer season, it can be said that they are inefficient and should have use blend of DMU1, 10 and 12 mode of operation with different proportions in order to be efficient. Specifically, DMU7, 18 and 19 should use more of DMU 1 way of operation as a reference then DMU 10 and 12. Due to Covid 19 pandemic, it is inefficient between the DMU 26 and DMU 32. DMU26 and DMU27 has to focus more on mode of operation in DMU 1 and then DMU11 and DMU 12. When it is looked at the DMU 29, 30, 31, it should be focused more on DMU12, 15 and 17 modes of operation as a reference to increase efficiency.

In total weight table for total cheese production in Appendix C.2, the company efficiency is very dependent on sales followed by production amount and processed milk amount. The findings of DEA is consistent with expectations. Increasing milk input to the company results in more production and sales.

Each production parameter is studied for each DMU and target percentages are calculated in to reach 100% efficiency in Target Table for Total Cheese Production in Appendix C.3. Inefficient DMUs has been compared to efficient DMUs and target values have been calculated for each index for each DMU to be considered as efficient. The system has been worked as input oriented, where percentage input values, index1,2,3,4,5 are given while output is being kept constant. It can be seen that, one of the major causes of inefficiency is high energy cost. Especially for DMUs 7, 8, 9 and DMUs 18, 19, 20 energy costs are targeted to decrease by 32% and 50 % respectively. The main reason is both time intervals correspond to summer season. In Dairy Sector, cold chain must be maintained not to violate food safety standards. In hot weathers, more energy is required to keep the tanks, pipeline and storage room at desired temperature. In both intervals, nearly 5% decrease in processed milk amount and 3% decrease in labor costs are targeted. This also shows that loss and energy loss play a big role on increasing efficiency. For DMUs26, 27, 28,29,30,31 and 33, 34 and 35 both labor costs and loss are targeted to decrease approximately by 13% to reach efficiency. This period corresponds to Covid 19 Pandemic. Targeted 30% decrease in

Electric Costs combined with nearly 20 % decrease in processed milk amount, KOOP would have been efficient in pandemic period.

In Appendix C4, the Cross efficiencies in Total Cheese production are evaluated, DMU 1 and 12 are one of the most significant DMUs where when the operating conditions applied it would provide efficiency in pandemic period as well. When the raw data is checked, it is shown that whey protein waste is very low despite high production capacity. The combined DMU 10 and DMU 11 operating conditions are also very well applicable to nearly all DMUs for 100% efficiency. DMU 11 has lower production loss amount and higher sales than DMU 10 with similar production quantities and whey protein.

In Appendix D, the most efficient DMUs' production parameters which are the most applicable by other DMUs to be efficient are compared between Hellim, White Cheese and Total Production. DMU 1 is the only common month which is efficient and has the most favorable operating conditions. When the raw data is examined, it could be seen that loss ratio is low for all products, the production capacity is high for white cheese production and total processed milk quantity is low followed by low production capacity and low sales quantities. Main reason low energy costs, which provided increase in efficiency.

Chapter 5

SUGGESTION AND DISCUSSION

As mentioned previously, like other cheese manufacturers in TRNC, KOOP purchases the milk from SUTEK and accepts any milk which is analyzed and confirmed by SUTEK. Most of the time milk coming from the farmers are from Cold Chain System, however there are still many farmers which supplies warm milk especially sheep and goat milk. Cooled Chain System has also been popular in the island where warm milk system is adapted to cold system by additional pipeline and storage. Warm milk has higher somatic cell counts and since it is very important in Hellim Production with PDO it cannot be ignored. Therefore, low quality milk acceptance causes low quality cheese production which decreases the efficiency of the factory. DEA also confirmed the fact that the factory has lower efficiency in summer seasons. The situation is aimed to be developed during the transition process of Hellim Export to EU Market by 2024.

Additionally, poor animal welfare in summer season, causes low milk quality and yield which also causes low quality cheese production in the factory. Since KOOP is a big company and owned by Central Bank of Turkish Cypriot Cooperative, KOOP Bank, It is suggested that low interest loan programs could be arranged for farmers in order to improve their farm facilities, improving food safety and animal welfare. Investments in cold chain system and cold storage tanks would lower somatic cell count and prevent milk spoilage.

Animal welfare could easily improve with some investments, such as partitioning of animals in shelters, increased ventilation systems, renovated floor to prevent accumulation of manure, manure spreaders would increase animal welfare, milk yield and quality specifically in summer season.

Another factor which decreases efficiency of the factory in summer season is high energy costs of the factory. Since Milk and Dairy Products are very perishable products, keeping them at low temperatures are more difficult in hot weathers and causes high electric costs. In order to prevent high energy consumptions in the factory, building of photovoltaic system could be considered. Since the amount of sunlight is very high in TRNC in summer season, the major amount of the energy requirement could be used from the energy produced by solar panels.

In Pandemic period starting from February, 2020, the efficiency of the factory decreased similar to all other sectors in the business. According to DEA, slide contraction of company in the period, for example, decreasing the processing capacity would also decrease production loss and energy costs of the company would have ended up with higher efficiency. Furthermore, in pandemic periods and in efficient months generally summer months, the whey protein as a waste is aimed to decrease significantly in both cheese types and general cheese production. In other words, whey protein must be decreased for increased efficiency. Technically, it is not possible to decrease the amount of produced whey protein, however it could be used to produce other products. The whey protein is a waste of all cheese manufacturers, therefore by gathering all together, whey protein processing plant could be built to product milk powder from whey protein. Milk powder is a great product which could be used as an ingredient to many products in the market such as chocolate, cereals, supplements, soup and sauces. Milk powder production is high-cost investment, however considering the high amount of waste of whey protein going to drainage, it is very efficient in long term. As mentioned previously, the production losses cause decrease in the total efficiency of production. The main reason behind the production loss should be investigated further to understand if it is due to machinery or product quality. Machinery related issues must be eliminated by regular maintenance and repair. Renovation of specific equipment could also decrease the production losses significantly. Since Sales has the highest weight on efficiency of the factory, in order to increase the sales amounts, the KOOP Factory could focus more on advertisement and emphasize the domestic production by public service ads. Table 8 is formed by interpreting the data from Appendix C.3 Target Table for Total Cheese Production as an example of an efficient Total Cheese Production. In order to be efficient processed milk amount of the factory should be decreased which would cause decrease in production costs and product amount. The most significant decrease is targeted in Pandemic Period. However, all milk in the market which cannot be sold to other manufacturers is supplied to KOOP Factory. Since milk is very perishable product and must be processed within maximum of 4 days of acceptance when stored at between 2-4C. As suggested, decreasing the processed amount of milk is not very applicable for the sector because unprocessed milk must be disposed after 3-4 days due to food safety regulations. (2016)

Table 8: Suggested Production Parameters for Efficient Total Cheese Production

Name	Target Processed Milk (ton)	Target Labor costs (TL/month)	Target Loss	Target Electric Costs	Target Production Amount
DMU01	1975,8	1023542,2	1%	206334,3	264,6
DMU02	1577,0	887152,3	1%	258303,5	248,2
DMU03	1801,2	971359,8	2%	221003,4	273,8
DMU04	2096,8	943161,7	2%	311802,4	310,0
DMU05	2044,4	1109489,6	2%	349686,6	310,6
DMU06	1843,6	1008498,6	2%	373610,2	282,0
DMU07	1711,5	1201909,1	1%	498823,8	273,4
DMU08	2113,4	1125475,3	2%	407387,0	274,1
DMU09	1805,0	1039753,1	2%	489040,5	255,5
DMU10	1923,2	1023255,6	2%	315098,9	279,8
DMU11	1976,7	1093579,2	1%	293838,6	302,0
DMU12	2018,7	1797985,2	1%	253267,6	273,9

Similar to the Table 8, in Table 9 and 10, the production parameters such as loss energy costs are targeted to decrease by decreasing production capacity, this could be applied to some extent. Since Hellim and White Cheese are one of the most consumed dairy products and specifically Hellim is the second most exported product in North Cyprus, decreasing the production capacity is not very convenient when considering supply and demand equilibrium**.** The techniques to decrease production loss and energy costs mentioned previously would increase the efficiently more while keeping the production capacities constant.

Table 9: Suggest Production Parameters for Efficient White Cheese Production

Name	Target Processed Milk (ton)	Target Labor costs (TL/month)	Target Loss	Target Energy Cost	Target Production amount (ton)	Target Sales (TL/month)	Target 1/Whey Protein
DMU01	65,71	35.279,63	0,13	3.415,06	10,59	117.134,90	0,52
DMU02	42,62	34.986,09	0,16	3.198,78	7,17	98.746,50	0,44
DMU03	44,12	39.893,21	0,12	2.866,30	7,73	116.701,56	0,56
DMU04	27,65	42.346,89	0,16	2.280,33	4,74	166.502,67	0,57
DMU05	25,78	41.249,35	0,12	2.485,63	4,40	112.449,79	0,58
DMU06	28,11	40.514,52	0,15	2.971,11	4,55	147.916,50	0,68
DMU07	26,47	43.527,35	0,13	2.090,56	4,74	138.829,79	0,73
DMU08	13,16	42.107,16	0,13	1.628,99	2,23	156.820,67	0,95
DMU09	4,27	46.308,99	0,13	1.038,33	0,77	152.194,33	1,00
DMU10	16,58	37.845,54	0,14	2.031,38	2,80	141.877,37	0,68
DMU11	7,86	46.628,45	0,13	1.664,84	1,43	129.562,92	0,75
DMU12	4,58	68.870,88	0,16	839,91	0,79	168.417,50	0,67

Table 10: Suggested Production Parameters for Efficient Hellim Production

Name	Target Processed Milk (ton)	Target Labor costs (TL/month)	Target Loss	Target Electric Costs (TL)	Target Production amount(ton)	Target Sales (TL/month)	Target 1/Whey
DMU 01	383,61	134.254,90	0,19	38.671,56	47,95	1.692.487,67	0,03
DMU 02	369,36	137.610,75	0,14	42.386,14	46,17	1.738.122,59	0,04
DMU 03	362,76	122.631,06	0,18	36.693,93	45,34	1.600.526,05	0,04
DMU 04	354,80	124.519,84	0,22	41.240,13	44,35	1.700.533,00	0,04
DMU 05	334,82	140.569,03	0,15	43.022,19	41,85	1.737.590,67	0,04
DMU 06	314,90	149.576,84	0,16	50.428,09	39,36	1.866.365,33	0,05
DMU 07	266,82	140.116,44	0,17	41.793,91	33,35	1.626.735,87	0,04
DMU 08	217,65	148.332,36	0,23	41.541,15	27,21	1.369.939,83	0,06
DMU 09	257,91	151.861,73	0,18	51.489,27	32,24	1.394.275,67	0,05
DMU 10	255,38	137.337,49	0,18	40.076,96	31,92	1.165.719,27	0,06
DMU 11	280,28	164.794,78	0,22	46.444,67	35,03	1.721.820,33	0,05
DMU 12	288,26	156.434,95	0,15	43.600,41	36,03	1.683.262,29	0,05

Chapter 6

CONCLUSION

6.1 Conclusion

The study provided KOOP Factory to evaluate their efficiency in Hellim, White Cheese and Total Cheese Production from DEA aspect between the years 2018 and 2020. It is a fact that there are some climatic and political parameters which cannot be modified in short term such as low milk yield in summer season and low Hellim yield due to lack of Sheep and Goat milk in the market. The new agreement for Export of Hellim with PDO via Green Line would promote increase in Hellim yield and quality by 2024. High Production Losses and High Energy Costs are the main parameters which are aimed to be decreased for increased efficiency. Installation of Photovoltaic Systems and increasing the maintenance and repair activities in the factory would decrease the Production Costs significantly. Another big issue of the factory is the disposal of large amounts of Whey Protein similar to other Dairy Processors. Whey Protein is very high nutrient product which is wasted into storm drain due to lack of processing facilities. Whey Protein Processing Facilities would increase the factory efficiency considerably by both selling by-products such as milk powder and by increasing the environmental efficiency of the factory. Under the scope of the study, there have been some limitations due to ongoing Covid-19 outbreak since 2020 in TRNC. The factory experienced two shut downs due to the outbreak where production continued under various limitations. In the study, the main reason of the low efficient period in 2020 was the outbreak therefore the main causes related to production could not be revealed.

6.2 Future Work

Due to Covid-19 measures, there is low chance of visiting the factory. Visiting the site could have been very useful to analyze the production loss and energy losses better. Furthermore, the variety of products is very high and differs in categories. The factory used to start up as a dairy plant however now it produces fruit juices as well. Dairy products consist of many cheese types, yoghurt, milk and ice-cream. In order to be able to evaluate the efficiency of the factory whole data must be studied by DEA and reach a result. Due to the scope of the study and time restrictions, a new study must be performed as a future work for further evaluation. Thankfully, KOOP Factory has a good recording system of production data which facilitated the use of data in DEA with no difficulties. The production manager was very helpful and eager to share the data. Despite, it is a challenge, to transform the data in DEA Format. Additionally, a new study on environmental sustainability of the company could be studied. All in all, benchmarking study with other dairy plants in TRNC would enlighten the facts in dairy sector significantly.

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APPENDICES

Appendix A: DEA Results for Hellim Production

A. 1 Efficiency Table for Hellim Production

Name	DMU01	DMU04	DMU06	DMU11	DMU17	DMU20	DMU21	DMU22	DMU25	DMU30	DMU35
DMU01	1	0	0	0	0	0	0	0	0	0	0
DMU02	0,78	0,22	0	0	0	0	0	0	0	0	0
DMU03	1	0	0	0	0	0	0	0	0	0	0
DMU04	0	1	0	0	0	0	0	0	0	0	0
DMU05	0,97	0,03	0	0	0	0	0	0	0	0	0
DMU06	0	0	1	0	0	0	0	0	0	0	0
DMU07	0,08	0	0,92	0	0	0	0	0	0	0	0
DMU08	0,46	0	0,54	0	0	0	0	0	0	0	0
DMU09	0,46	0	0,28	0,07	0,19	0	0	0	0	0	0
DMU10	0,72	0	0,26	0	0	0	0	0,02	0	0	0
DMU11	0	0	0	1	0	0	0	0	0	0	0
DMU12	0,48	0	0,11	0	0,16	0	0	0	0	0	0,25
DMU13	0,71	0,29	0	0	0	0	0	0	0	0	0
DMU14	0,76	0	0	0	0	0	0	0	0	0,24	0
DMU15	0,03	0,13	0	0,69	0	0	0	0	0,15	0	0
DMU16	0,06	0	0,28	0,39	0,17	0	0	0	0	0	0,1

Name	DMU01	DMU04	DMU06	DMU11	DMU17	DMU20	DMU21	DMU22	DMU25	DMU30	DMU35
DMU17	0	0	0	0	1	0	0	0	0	0	0
DMU18	0,44	0	0,13	0	0,38	0	0	0,05	0	0	0
DMU19	0,23	0	0,53	0,05	0,19	0	0	0	0	0	0
DMU20	0	0	0	0	0	1	0	0	0	0	0
DMU21	0	0	0	0	0	0	1	0	0	0	0
DMU22	0	0	0	0	0	0	0	1	0	0	0
DMU23	0,01	0	0,14	0	0,18	0	0	0,66	0	0	0
DMU24	0,16	0	0	0	0,66	0	0	0,18	0	0	0
DMU25	0	0	0	0	0	0	0	0	1	0	0
DMU26	0,27	0	0	0,08	0	0	0	0	0	0,65	0
DMU27	0,53	0	0	0,4	0,07	0	0	0	0	0	0
DMU28	0,34	0	0,19	0,42	0,05	0	0	0	0	0	0
DMU29	0,4	0	0	0,46	0,04	0	0	0	0	0,09	0
DMU30	0	0	0	0	0	0	0	0	0	1	0
DMU31	0	0	0	0	0,89	0	0	0	0	0,11	0
DMU32	0	0	0,01	0	0,36	0,45	0,18	0	0	0	0
DMU33	0	0	0	0	0,09	0	0,35	0,56	0	0	0
DMU34	0	0	0,57	0	0	0,28	0	0,15	0	0	0
DMU35	0	0	0	0	0	0	0	0	0	0	1
	21	**4**	**13**	**8**	**13**	**3**	**3**	**7**	**2**	**5**	**3**

A.2 Weight Table for Hellim Production

Name	**Input 1**	**Input 2**	**Input 3**	**Input 4**	**Input 5**	**Input 6**	**Input 7**
DMU01	1,37	0	0,41	0	0	0,71	0,72
DMU02	0	3,58	0	0	0	0,01	0
DMU03	0	3,57	0	0	0	0	0
DMU04	0,26	1,08	0	1,35	0	1,44	0
DMU05	0	3,07	0	0	0	0,01	0
DMU06	1,68	0	0,5	0	0	0,87	0,88
DMU07	0,63	0	0	3	0	0	0
DMU08	0,01	3,17	0	0	0	0	0
DMU09	0,44	1,85	0,33	0	0	0,63	0
DMU10	0,71	0,74	0,56	0	0	0	0
DMU11	0,57	1,01	0	0,63	0	1,33	0
DMU12	0,8	0	0,52	0,7	0	0,42	0
DMU13	0	2,62	0	0	0	0,01	0
DMU14	0	0,97	1,18	0	0	0	0
DMU15	0	0,59	0,08	1,34	0	1,33	0
DMU16	0,37	0,83	0,13	0,88	0	1,12	0
DMU17	1,25	0,72	0	0	0	1,27	0
DMU18	0,71	0,74	0,56	0	0	0,06	0
DMU19	0,3	1,25	0,23	0	0	0,43	0
DMU20	1,56	1,35	0	0	0	1,33	0,1
DMU21	1,52	0	0,59	0	0	0,15	0,09
DMU22	1,33	0	0,79	0	0	0	0,29
DMU23	0,97	0	0,71	0,36	0	0,02	0
DMU24	0,68	0	0,55	0,26	0	0	0
DMU25	0,09	0,48	0,13	1,06	0	1,13	0
DMU26	0	1,87	0,41	0	0	0,52	0
DMU27	0,22	1,31	0,27	0	0	0,44	0
DMU28	0,29	1,24	0,22	0	0	0,42	0
DMU29	0,2	1,17	0,25	0	0	0,39	0
DMU30	0,51	0,67	0	0,39	0	1	0
DMU31	0,27	0	1,88	0	0	0	0
DMU32	1,18	0	0,5	0,08	0	0,09	0
DMU33	1,47	0	0,61	0	0	0,11	0
DMU34	1,24	0	0,5	0,06	0	0	0
DMU35	1,62	0,94	0	0	0	1,65	0
Sum	22,25	34,82	11,91	10,11	0	16,89	2,08
Ranking	2	1	4	5	7	3	6

A. 3 Target Table for Hellim Production

Name	Index1 Gain (%)	Index2 Gain (%)	Index3 Gain (%)	Index4 Gain (%)	Index5 Gain (%)
DMU01	0	0	0	0	0
DMU02	-11,49	-0,03	-21,63	-12,59	-11,49
DMU03	-4,93	-0,46	-50	-8,39	-4,93
DMU04	0	0	0	0	0
DMU05	-25,15	-14,52	-15,02	-60,09	-25,15
DMU06	0	0	0	0	0
DMU07	-11,81	-21,97	-22,88	-11,81	-11,81
DMU08	-11,02	-11,02	-28,56	-50,45	-11,02
DMU09	-0,48	-0,48	-0,48	-36,09	-0,48
DMU10	-10,35	-10,35	-10,35	-47,35	-10,35
DMU11	0	0	0	0	0
DMU12	-10,75	-51,61	-10,75	-10,75	-10,75
DMU13	-33,25	-26,87	-31,08	-55,7	-33,25
DMU14	-34,91	-13,8	-13,8	-48,46	-34,91
DMU15	-23,41	-14,13	-14,13	-14,13	-23,41
DMU16	-10,4	-10,4	-10,4	-10,4	-10,4
DMU17	0	0	0	0	0
DMU18	-9,6	-9,6	-9,6	-47,09	-9,6
DMU19	-32,76	-32,76	-32,76	-68,3	-32,76
DMU20	0	0	0	0	0
DMU21	0	0	0	0	0
DMU22	0	0	0	0	0
DMU23	-1,53	-11,58	-1,53	-1,53	-1,53
DMU24	-28,35	-58,93	-28,35	-28,35	-28,35
DMU25	0	0	0	0	0
DMU26	-20,83	-5,46	-5,46	-10,03	-20,83
DMU27	-30,17	-30,17	-30,17	-51,02	-30,17
DMU28	-31,1	-31,1	-31,1	-53,28	-31,1
DMU29	-34,79	-34,79	-34,79	-51,82	-34,79
DMU30	0	0	0	0	0
DMU31	-16,21	-25,57	-16,21	-43,14	-16,21
DMU32	-15,15	-15,75	-15,15	-15,15	-15,15
DMU33	-1,2	-15,39	-1,2	-28,7	-1,2
DMU34	-14,6	-33,21	-14,6	-14,6	-14,6
DMU35	0	0	0	0	0

A.4 Cross Efficiency Table for Hellim Production

Name	DMU01	DMU04	DMU06	DMU11	DMU17	DMU20	DMU21	DMU22	DMU25	DMU30	DMU35
DMU 01	**100**	70,36	**100**	74,03	**100**	84,03	82,21	70,71	64,19	80,65	79,47
DMU 02	**100**	**100**	99,74	89,13	63	69	68,85	68,8	63,78	58,06	53,95
DMU 03	**100**	99,79	99,75	88,87	62,77	68,97	68,79	68,8	63,47	57,73	53,85
DMU 04	**100**	**100**	98,28	**100**	91,31	72,95	65,77	55,07	95,08	90,85	**100**
DMU 05	**100**	**100**	99,74	89,13	63	69	68,85	68,8	63,78	58,06	53,95
DMU 06	**100**	70,36	**100**	74,03	**100**	84,03	82,21	70,71	64,19	80,65	79,47
DMU 07	**100**	55,51	**100**	49,09	44,24	64,81	49,12	47,45	38,77	32,95	91,06
DMU 08	**100**	99,58	**100**	88,82	62,95	69,28	69,04	69	63,52	57,82	54,11
DMU 09	**100**	95,14	**100**	**100**	**100**	81,72	86,64	84,59	87,53	97,93	75,28
DMU 10	**100**	73,87	**100**	78,71	97,64	87,2	93,95	100	66,92	82,14	77,99
DMU 11	81,52	92,57	92,47	**100**	**100**	79,86	73,44	59,24	97,77	**100**	**100**
DMU 12	**100**	72,03	**100**	77,66	**100**	87,58	86,29	86,1	72	84,43	**100**
DMU 13	**100**	**100**	99,74	89,13	63	69	68,85	68,8	63,78	58,06	53,95
DMU 14	**100**	68,55	73,14	73,54	99,77	57,59	72,94	91,24	64,66	**100**	52,37
DMU 15	**100**	**100**	82,96	**100**	92,9	60,14	56,44	45,85	**100**	96,2	98,27
DMU 16	**100**	95,95	**100**	**100**	**100**	79,45	74,73	65,31	95,5	97,7	**100**
DMU 17	54,46	67,82	75,46	81,65	**100**	87,12	78,32	58,03	84,6	96,55	**100**
DMU 18	**100**	74,93	**100**	80,29	**100**	87,5	94,46	**100**	69,06	85,24	79,02
DMU 19	**100**	95,14	**100**	**100**	**100**	81,72	86,64	84,59	87,53	97,93	75,28
DMU 20	76,49	79,57	**100**	89,32	**100**	**100**	89,72	72,64	84,43	92,46	**100**
DMU 21	87,97	63,2	**100**	69,64	**100**	**100**	**100**	98,61	61,6	77,41	95,14
DMU 22	**100**	65,35	**100**	69,43	99,8	90,07	95,53	**100**	58,18	75,58	81,66

Name	DMU01	DMU04	DMU06	DMU11	DMU17	DMU20	DMU21	DMU22	DMU25	DMU30	DMU35
DMU 23	**100**	67,12	**100**	72,24	**100**	90,16	93,87	**100**	63,46	79,15	90,41
DMU 24	**100**	66,53	98,08	71,6	**100**	87,8	92,68	**100**	62,86	79,41	87,66
DMU 25	**100**	97,3	86,59	**100**	98,15	65,33	62,13	52,13	**100**	**100**	**100**
DMU 26	**100**	97,16	86,47	**100**	94,72	66,16	74,94	76,98	86,87	**100**	61,2
DMU 27	**100**	95,19	95,77	**100**	**100**	77,14	83,74	83,13	87,87	**100**	71,51
DMU 28	**100**	95,14	**100**	**100**	**100**	81,72	86,64	84,59	87,53	97,93	75,28
DMU 29	**100**	95,19	95,77	**100**	**100**	77,14	83,74	83,13	87,87	**100**	71,51
DMU 30	72,23	85,63	85,62	95,36	**100**	78,79	72,29	56,63	95,44	**100**	**100**
DMU 31	76,26	47,18	54,3	53,34	**100**	45,64	61,48	83,18	50,24	**100**	43,96
DMU 32	87,75	63,35	**100**	70,08	**100**	**100**	**100**	99,93	62,54	77,95	97,36
DMU 33	84,77	61,62	97,28	68,64	**100**	98,92	**100**	**100**	61,45	77,92	94,92
DMU 34	87,14	61,58	**100**	67,53	95,8	**100**	99,44	**100**	59,05	72,88	95,35
DMU 35	54,46	67,82	75,46	81,65	**100**	87,12	78,32	58,03	84,6	96,55	**100**
	25	**5**	**17**	**11**	**21**	**4**	**3**	**6**	**2**	**8**	**9**

Appendix B: DEA Results for White Cheese Production

B.1 Weight Table for White Cheese Production

Name	Input 1	Input2	Input3	Input 4	Input 5	Input6	Input 7
DMU01	0	1,27	0,85	0,45	0	0	0,07
DMU02	0	2,85	0,12	0,16	0,1	0	0
DMU03	0,11	1,9	0,6	0,03	0	0,14	0
DMU04	0	0,91	0,99	0	0	0,49	0
DMU05	0	2,33	0,28	0	0,12	0	0,03
DMU06	0	2,92	0,1	0	0,21	0	0
DMU07	0	2,02	0,26	0	0,11	0	0
DMU08	0	1,12	0,87	0	0	1,1	0
DMU09	0	1,26	0,79	0,26	0	1,12	0
DMU10	0	2,89	0,1	0	0,2	0	0
DMU11	0,16	1,18	0,8	0,46	0	0	0
DMU12	0	0	0,39	4,88	14,59	0	0
DMU13	0	1,13	0,63	0,41	0,02	0	0
DMU14	0,17	2,3	0,09	0	0	0	0
DMU15	0	1,12	0,82	0,78	0	0	0
DMU16	0	1,2	0	14,62	0	0	0
DMU17	0,08	0,94	0,71	0	0	0,18	0
DMU18	0	1,24	0,75	0	0	0	0,95
DMU19	0	1,02	0,81	0	0	0	0,9
DMU20	0	0	1,67	0	0	0,75	0,43
DMU21	8,31	0,53	0,83	0	0	0,27	0,79
DMU22	0,17	2,23	0,08	0	0	0	0
DMU23	0	1,14	0,9	0	0	0	1
DMU24	0	0	1	0	0	0,38	0,31
DMU25	0	0,99	0,58	0	0,1	0	0,07
DMU26	0,08	0,9	0,68	0	0	0,17	0
DMU27	0	1,12	0,68	0	0	0	0,86
DMU28	0	1,02	0,79	0	0	1,01	0
DMU29	0	0	1,54	0	0	0	0
DMU30	0	0,33	1,2	0	0	0,26	0
DMU31	0	0	1,11	0	0	0,5	0
DMU32	0,08	0,89	0,67	0	0	0,17	0
DMU33	0	0	1,82	0	0	0,69	0,56
DMU34	0	0,86	0,65	0	0,08	0,16	0
DMU35	0	0,25	0	4,45	17,23	0	0,88
Sum	9,16	39,86	24,16	26,5	32,76	7,39	6,85
Rank	**5**	**1**	**4**	**3**	**2**	**6**	**7**

B.2 Lambda Table for White Cheese Production

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU08	DMU09	DMU11	DMU12	DMU15	DMU16	DMU20	DMU21	DMU23	DMU28	DMU33
DMU01	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU02	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU03	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU04	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
DMU05	0,05	0	0,29	0	0	0	0,04	0,63	0	0	0	0	0	0	0	0
DMU06	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
DMU07	0,01	0	0,68	0	0	0	0	0,32	0	0	0	0	0	0	0	0
DMU08	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
DMU09	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
DMU10	0	0	0	0,07	0	0	0,38	0,55	0	0	0	0	0	0	0	0

Name	DMU11	DMU12	DMU13	DMU14	DMU15	DMU16	DMU17	DMU18	DMU19	DMU20	DMU21
DMU01	0	0	0,03	0	0	0	0,08	0	0	0	0
DMU02	0	0	0	0	0	0	0	0	0	0	0
DMU03	0	0	0	0	0	0	0	0	0	0	0
DMU04	0	0	0	0,33	0	0	0	0	0	0	0
DMU06	0	0	0	0	0	0	0	0	0	0	0
DMU08	0	0	0	0	0	0	0	0,43	0	0	0
DMU09	0	0	0,84	0,33	0	0	0,17	0	0	0	0
DMU11	1	0	0,01	0,34	0	0	0,29	0	0	0	0
DMU12	0	1	0	0	0	0	0	0	0	0	0
DMU15	0	0	0,13	0	1	0	0	0	0	0	0
DMU16	0	0	0	0	0	1	0	0	0	0	0
DMU20	0	0	0	0	0	0	0,46	0,57	0,67	1	0
DMU21	0	0	0	0	0	0	0	0	0	0	1
DMU23	0	0	0	0	0	0	0	0	0,33	0	0
DMU28	0	0	0	0	0	0	0	0	0	0	0
DMU33	0	0	0	0	0	0	0	0	0	0	0

Name	DMU22	DMU23	DMU24	DMU25	DMU26	DMU27	DMU28	DMU29	DMU30	DMU31
DMU01	0	0	0	0,2	0,19	0	0	0	0,05	0
DMU02	0	0	0	0	0	0	0	0	0	0
DMU03	0	0	0	0	0	0	0	0	0	0
DMU04	0,06	0	0	0	0	0	0	0	0	0
DMU06	0	0	0	0	0	0	0	0	0	0
DMU08	0	0	0	0	0	0,31	0	0	0	0
DMU09	0,77	0	0	0,31	0,15	0	0	0	0	0
DMU11	0,17	0	0	0,35	0,44	0	0	0	0	0
DMU12	0	0	0	0	0	0	0	0	0	0
DMU15	0	0	0	0,13	0	0	0	0,43	0	0
DMU16	0	0	0	0	0	0	0	0	0	0
DMU20	0	0	0,53	0	0,22	0,69	0	0	0,83	0,43
DMU21	0	0	0	0	0	0	0	0	0	0
DMU23	0	1	0	0	0	0	0	0,57	0	0
DMU28	0	0	0	0	0	0	1	0	0	0,57
DMU33	0	0	0,47	0	0	0	0	0	0,13	0

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU08	DMU09	DMU11	DMU12	DMU15	DMU16	DMU20	DMU21	DMU23	DMU28	DMU33
DMU32	0,13	0	0	0	0	0	0,06	0,07	0	0	0	0,74	0	0	0	0
DMU33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
DMU34	0,13	0	0	0	0	0	0,02	0,3	0	0	0	0,55	0	0	0	0
DMU35	0	0	0	0	0	0	0,62	0	0,3	0	0	0	0,08	0	0	0
	10	1	3	4	1	3	12	12	2	3	1	11	2	3	2	3

B.3 Target Table for White Cheese Production

Name	Index1 Gain (%)	Index2 Gain (%)	Index3 Gain (%)	Index4 Gain (%)	Index5 Gain (%)
DMU01	0	0	0	0	0
DMU02	0	0	0	0	0
DMU03	0	0	0	0	0
DMU04	0	0	0	0	0
DMU05	-12,52	-7,28	-7,28	-21,9	-7,28
DMU06	0	0	0	0	0
DMU07	-27,49	-18,82	-18,82	-50,25	-18,82
DMU08	0	0	0	0	0
DMU09	0	0	0	0	0
DMU10	-2,63	-0,75	-0,75	-27,94	-0,75
DMU11	0	0	0	0	0
DMU12	0	0	0	0	0
DMU13	-21,28	-15,55	-15,55	-15,55	-15,55
DMU14	-20,48	-20,48	-20,48	-29,56	-28,3
DMU15	0	0	0	0	0
DMU16	0	0	0	0	0
DMU17	-20,46	-20,46	-20,46	-33,48	-27,6
DMU18	-47,73	-5,12	-5,12	-55,61	-47,99
DMU19	-64,5	-10,26	-10,26	-67,15	-61,34
DMU20	0	0	0	0	0
DMU21	0	0	0	0	0
DMU22	-22,84	-22,84	-22,84	-31,11	-27,08
DMU23	0	0	0	0	0
DMU24	-66,59	-55,83	-42,37	-53,99	-71,86
DMU25	-29,18	-28,05	-28,05	-54,78	-28,05
DMU26	-25,34	-25,34	-25,34	-44,27	-28,66
DMU27	-62,21	-13,89	-13,89	-40,29	-63,2
DMU28	0	0	0	0	0
DMU29	-69,48	-15,38	-15,38	-74,29	-68,02
DMU30	-76,48	-15,53	-15,53	-85,79	-79,1
DMU31	-91,83	-29,74	-26,99	-94,49	-91,29
DMU32	-24,15	-24,15	-24,15	-78,04	-38,98
DMU33	0	0	0	0	0
DMU34	-28,77	-27,96	-27,96	-61,18	-27,96
DMU35	-15,01	-12,21	-13,48	-12,21	-12,21

B.4 Total Cross Efficiency of White Cheese Production

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU08	DMU09	DMU11	DMU12	DMU15	DMU16	DMU20	DMU21	DMU23	DMU28	DMU33
DMU01	**100**	77,51	95,96	87,02	74,56	97,08	**100**	96,8	58,19	100	78,04	**100**	92,81	98,94	90,35	94,1
DMU02	97,44	100	100	100	98,02	98,59	**100**	98,44	44,05	83,53	81,98	80,64	79,78	74,15	74,52	68,4
DMU03	**100**	80,34	100	100	88,35	99,72	**100**	**100**	52,55	91,68	78,68	91,36	86,93	85,03	84,97	81,09
DMU04	96,22	53,06	93,9	100	77,15	100	99,15	90,62	64,22	89,86	71,82	**100**	91,38	89,25	98,11	91,22
DMU05	**100**	94,13	100	99,76	94,67	99,58	**100**	**100**	46,67	87,73	80,07	85,24	82,98	79,61	77,85	73,97
DMU06	93,07	99,52	96,78	100	100	99,17	**100**	99,94	43,49	82,86	81,94	80,25	79,51	73,58	73,91	67,9
DMU07	**100**	93,42	100	99,62	94,79	97,04	97,47	**100**	45,64	87,14	79,33	83,31	81,04	77,87	76,06	72,39
DMU08	52,01	14,07	66,38	96,65	66,97	100	98,14	63,2	64,74	53,47	61,48	87,35	81,98	60,27	100	69,12
DMU09	46,93	14,05	62,7	91,24	64,35	100	**100**	61,23	64,52	51,36	62,98	86,2	81,84	58,81	100	67,05
DMU10	93,21	99,38	96,85	100	99,88	99,17	**100**	**100**	43,57	83	81,92	80,38	79,6	73,73	74,01	68,05
DMU11	89,47	76,51	91,07	84,78	74,48	96,1	**100**	**100**	58,49	100	80,61	**100**	92,96	98,94	90,54	94,16
DMU12	5,98	12,38	8,04	10,12	11,47	44,9	98,49	36,86	100	24,85	93,11	92,61	100	77,8	100	84,97
DMU13	**100**	80,81	97,88	89,53	78,34	96,58	**100**	**100**	56,81	100	80,78	97,82	91,47	95,98	88,82	90,96
DMU14	92,4	99,13	97,78	100	99,12	99,28	**100**	**100**	43,66	82,98	81,81	80,47	79,7	73,97	74,15	68,2
DMU15	93,53	76,54	92,85	83,18	72,06	94,74	**100**	96,55	59,59	100	80,87	**100**	92,94	99,1	91,34	94,25
DMU16	16,38	27,62	21,35	18,15	16,92	48,3	**100**	30,85	79,29	35,73	100	64,49	70,72	58,34	88,23	52,47
DMU17	**100**	69,17	98,1	98,12	81,52	99,97	100	**100**	59,95	97,83	76,68	**100**	92,29	94,46	93,26	92,57
DMU18	20,91	28,95	19	20,94	7,49	100	99,83	27,14	56,55	53,81	40,03	**100**	92,58	98,81	89,13	94
DMU19	20,52	27,4	18,45	20,15	7,11	96,94	96,8	26,55	56,97	53,9	38,72	**100**	91,66	100	88,68	95,67
DMU20	37,98	15,25	42,85	57,1	34,7	88,19	87,26	45,87	70,39	58,79	46,32	**100**	86,85	89,72	100	98,33
DMU21	2,6	6,71	4,47	7,72	5,44	71,21	100	22,33	71,99	21,44	45,58	100	100	92,75	100	94,75
DMU22	92,4	99,13	97,78	100	99,12	99,28	100	**100**	43,66	82,98	81,81	80,47	79,7	73,97	74,15	68,2
DMU23	20,52	27,4	18,45	20,15	7,11	96,94	96,8	26,55	56,97	53,9	38,72	**100**	91,66	100	88,68	95,67

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU08	DMU09	DMU11	DMU12	DMU15	DMU16	DMU20	DMU21	DMU23	DMU28	DMU33
DMU24	34,9	15,99	38,58	50,71	30,13	86,92	86,13	42,33	68,77	58,13	44,03	**100**	86,68	92,73	97,78	100
DMU25	**100**	78,12	95,33	90,85	78,72	99,42	100	**100**	56,56	100	76,52	99,9	92,66	98,44	89,09	93,76
DMU26	**100**	69,17	98,1	98,12	81,52	99,97	100	**100**	59,95	97,83	76,68	**100**	92,29	94,46	93,26	92,57
DMU27	20,91	28,95	19	20,94	7,49	100	99,83	27,14	56,55	53,81	40,03	**100**	92,58	98,81	89,13	94
DMU28	52,01	14,07	66,38	96,65	66,97	100	98,14	63,2	64,74	53,47	61,48	87,35	81,98	60,27	100	69,12
DMU29	**100**	55	84,62	73,33	57,89	73,33	73,33	84,62	55	100	57,89	91,67	78,57	100	78,57	100
DMU30	**100**	53,85	90,76	87,92	67,62	88,55	88,12	89,5	63,02	97,85	65,95	**100**	88,12	98,28	92,5	100
DMU31	76,72	32,29	75,63	84,37	59,37	88,19	87,26	75,37	70,39	82,04	59,78	**100**	86,85	89,72	100	98,33
DMU32	**100**	69,17	98,1	98,12	81,52	99,97	100	**100**	59,95	97,83	76,68	**100**	92,29	94,46	93,26	92,57
DMU33	34,9	15,99	38,58	50,71	30,13	86,92	86,13	42,33	68,77	58,13	44,03	**100**	86,68	92,73	97,78	100
DMU34	**100**	69,13	97,27	97,87	81,61	99,88	100	**100**	59,92	97,84	76,74	**100**	92,27	94,36	93,2	92,54
DMU35	0,77	3,3	1,04	1,61	0,78	39,68	100	8,05	100	10,01	49,88	87,32	100	69,1	95,99	77,05
	12	1	4	7	1	6	19	13	2	6	1	18	3	3	7	4

Appendix C: DEA Results for Total Cheese Production

Appendix C.1 Lambda Table for Total Cheese Production

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU10	DMU11	DMU12	DMU15	DMU17	DMU21	DMU25	DMU32
DMU01	1	0	0	0	0	0	0	0	0	0	0	0	0
DMU02	0	1	0	0	0	0	0	0	0	0	0	0	0
DMU03	0	0	1	0	0	0	0	0	0	0	0	0	0
DMU04	0	0	0	1	0	0	0	0	0	0	0	0	0
DMU05	0,79	0	0	0	0	0,14	0	0,07	0	0	0	0	0
DMU06	0	0	0	0	1	0	0	0	0	0	0	0	0
DMU07	0,75	0	0	0	0	0,07	0,03	0,14	0	0	0,01	0	0
DMU08	0,21	0,57	0	0	0	0,17	0	0,05	0	0	0	0	0
DMU09	0,13	0,14	0	0	0	0,71	0	0,01	0	0	0	0	0

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU10	DMU11	DMU12	DMU15	DMU17	DMU21	DMU25	DMU32
DMU10	0	0	0	0	0	1	0	0	0	0	0	0	0
DMU11	0	0	0	0	0	0	1	0	0	0	0	0	0
DMU12	0	0	0	0	0	0	0	1	0	0	0	0	0
DMU13	0,5	0	0	0	0	0,38	0	0,12	0	0	0	0	0
DMU14	0,55	0,45	0	0	0	0	0	0	0	0	0	0	0
DMU15	0	0	0	0	0	0	0	0	1	0	0	0	0
DMU16	0,12	0	0	0,32	0	0	0,35	0,14	0	0,07	0	0	0
DMU17	0	0	0	0	0	0	0	0	0	1	0	0	0
DMU18	0,53	0	0	0	0	0,32	0	0,15	0	0	0	0	0
DMU19	0,56	0	0	0	0	0,19	0	0,25	0	0	0	0	0
DMU20	0	0,51	0	0	0	0,2	0	0,19	0	0	0,11	0	0

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU10	DMU11	DMU12	DMU15	DMU17	DMU21	DMU25	DMU32
DMU21	0	0	0	0	0	0	0	0	0	0	1	0	0
DMU22	0,02	0,04	0	0	0	0,43	0	0,09	0	0	0,42	0	0
DMU23	0,41	0	0	0	0	0,42	0	0,17	0	0	0	0	0
DMU24	0,07	0	0	0	0	0,53	0	0,4	0	0	0	0	0
DMU25	0	0	0	0	0	0	0	0	0	0	0	1	0
DMU26	0,33	0	0	0,32	0	0,07	0,16	0,12	0	0	0	0	0
DMU27	0,33	0	0	0,14	0	0	0,32	0,06	0	0,15	0	0	0
DMU28	0	0	0	0	0	0	1	0	0	0	0	0	0
DMU29	0	0	0	0	0	0	0,43	0,08	0,34	0,16	0	0	0
DMU30	0	0	0	0	0	0	0,33	0,06	0,28	0,33	0	0	0
DMU31	0,19	0	0	0	0	0	0,12	0,34	0,35	0	0	0	0

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU10	DMU11	DMU12	DMU15	DMU17	DMU21	DMU25	DMU32
DMU32	0	0	0	0	0	0	0	0	0	0	0	0	1
DMU33	0	0,67	0	0	0	0	0	0,15	0	0	0,18	0	0
DMU34	0,55	0	0	0	0	0,32	0	0,13	0	0	0	0	0
DMU35	0,07	0	0	0,27	0	0	0,35	0,3	0	0	0,01	0	0

Appendix C.2 Weight Table for Total Cheese Production

Name	Input1	Input 2	Input3	Input4	Input5	Input6	Input7
DMU01	0	0,19	0,03	0,01	1,75	1,59	0
DMU02	0	0,38	0	0	1,78	1,54	0,05
DMU03	0	0,81	0	0,15	1,32	1,19	0,25
DMU04	0	0,14	0,02	0,01	1,29	1,18	0
DMU05	0,08	0	0	0	1,68	1,54	0
DMU06	0	0,37	0	0	1,62	1,4	0,05
DMU07	0	0,09	0,04	0	1,62	1,41	0,06
DMU08	0	0,01	0	0	1,82	1,52	0,03
DMU09	0	0,03	0,01	0	1,53	1,28	0,04
DMU10	0	0,15	0,02	0,01	1,37	1,25	0
DMU11	0	0,14	0,02	0,01	1,29	1,17	0
DMU12	0	0,12	0,02	0,07	1,18	1,09	0,09
DMU13	0	0	0,01	0	1,59	1,39	0
DMU14	0	0	0,43	0	1,55	0	0
DMU15	1,19	0,05	0	0	0,4	1,51	0
DMU16	0,23	0,02	0	0	1,15	1,26	0
DMU17	0,09	0,01	0	0	1,06	1,05	0
DMU18	0	0	0	0	1,61	1,36	0,01
DMU19	0,08	0	0	0	1,54	1,41	0
DMU20	0	0,02	0	0	1,66	1,39	0,03
DMU21	0	0,75	0	0,95	0	0,35	0,75
DMU22	0,02	0,02	0	0	1,48	1,26	0,03
DMU23	0	0	0	0	1,57	1,32	0,01

Name	Input1	Input 2	Input3	Input4	Input5	Input6	Input7
DMU24	0,07	0	0	0	1,37	1,25	0
DMU25	0	0,1	0,29	0,99	0,38	1,54	0
DMU26	0	0,01	0,02	0,03	1,23	1,13	0
DMU27	0,2	0,02	0	0	1,03	1,11	0
DMU28	0	0	2,73	0	0	0	0
DMU29	1,23	0,05	0	0	0	1,2	0
DMU30	1,23	0,05	0	0	0	1,2	0
DMU31	1,36	0,05	0	0	0	1,32	0
DMU32	0	0,17	0,2	0,74	0,32	1,85	0,09
DMU33	0	0	0,26	0	1,3	0	0,44
DMU34	0	0	0	0	1,37	1,16	0,01
DMU35	0	1	0,17	0,87	0	0,61	0,78
Sum	5,78	4,75	4,27	3,84	38,86	40,83	2,72
Ranking	3	4	5	6	2	1	7

Appendix C.3 Total Target Table for Total Cheese Production

Name	Index1 Gain (%)	Index2 Gain (%)	Index3 Gain (%)	Index4 Gain (%)	Index5 Gain (%)
DMU01	0	0	0	0	0
DMU02	0	0	0	0	0
DMU03	0	0	0	0	0
DMU04	0	0	0	0	0
DMU05	-0,41	-2,83	-53,9	-36,67	-0,41
DMU06	0	0	0	0	0
DMU07	-11,59	-1,27	-1,27	-26,29	-1,27
DMU08	-4,16	-0,18	-42,44	-44,28	-0,18
DMU09	-2,18	-1,26	-1,26	-26,77	-1,26
DMU10	0	0	0	0	0
DMU11	0	0	0	0	0
DMU12	0	0	0	0	0
DMU13	-7,01	-5,35	-1,56	-19,19	-1,56
DMU14	-11,04	-24,29	-1,41	-44,56	-1,41
DMU15	0	0	0	0	0
DMU16	-0,77	-0,77	-39,98	-23	-0,77
DMU17	0	0	0	0	0
DMU18	-5,23	-3,47	-25,27	-43,64	-1,54
DMU19	-1,48	-10,65	-57,06	-60,88	-1,48
DMU20	-5,76	-1,14	-33,39	-37,46	-1,14
DMU21	0	0	0	0	0
DMU22	-0,89	-0,89	-19,32	-5,25	-0,89
DMU23	-6,34	-11,3	-20,03	-33,38	-1,52
DMU24	-1,36	-49,01	-41,79	-9,33	-1,36
DMU25	0	0	0	0	0
DMU26	-19,05	-16,43	-16,43	-16,43	-16,43
DMU27	-16,14	-16,14	-16,14	-18,15	-16,14
DMU28	-12,67	-22,13	-9,09	-25,06	-14,42
DMU29	-14,66	-14,66	-14,66	-24,88	-15,69
DMU30	-11,64	-11,64	-11,64	-24,19	-15,63
DMU31	-14,4	-14,4	-14,4	-44,79	-16,06
DMU32	0	0	0	0	0
DMU33	-18,3	-15,89	-13,59	-56,69	-13,59
DMU34	-21,96	-21,55	-20,95	-35,44	-16,79
DMU35	-19,71	-5,31	-5,31	-5,31	-16,17

Appendix C.4 Cross Efficiency of Total Cheese Production

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU10	DMU11	DMU12	DMU15	DMU17	DMU21	DMU25	DMU32
DMU01	**100**	98,62	97,27	**100**	98,33	**100**	**100**	94,48	96,92	98,08	96,16	83,94	83,89
DMU02	**100**	**100**	99,22	**100**	99,94	**100**	98,91	90,24	96,4	96,18	98,07	82,15	82,3
DMU03	99,17	**100**	**100**	**100**	**100**	98,56	97,54	84,72	92,35	91,48	**100**	79,52	80,96
DMU04	**100**	98,62	97,27	**100**	98,33	**100**	**100**	94,48	96,92	98,08	96,16	83,94	83,89
DMU05	**100**	99,01	97,92	99,7	98,31	**100**	99,29	**100**	98,78	99,15	98,14	83,45	83,57
DMU06	**100**	**100**	99,17	**100**	**100**	**100**	98,99	89,79	96,2	96,04	98,06	82,12	82,31
DMU07	**100**	99,59	97,46	98,49	99,4	**100**	**100**	**100**	96,38	97,9	**100**	83,28	84,16
DMU08	**100**	**100**	98,94	99,1	99,33	**100**	98,66	**100**	98,14	98,09	99,7	82,76	83,07
DMU09	**100**	**100**	98,7	98,91	99,45	**100**	98,91	**100**	97,69	97,96	**100**	82,78	83,26
DMU10	**100**	98,62	97,27	**100**	98,33	**100**	**100**	94,48	96,92	98,08	96,16	83,94	83,89
DMU11	**100**	98,62	97,27	**100**	98,33	**100**	**100**	94,48	96,92	98,08	96,16	83,94	83,89
DMU12	**100**	99,08	97,95	**100**	98,53	**100**	**100**	**100**	96,46	97,85	**100**	83,7	84,8
DMU13	**100**	99,12	97,74	99,3	98,51	**100**	99,42	**100**	97,97	98,76	97,93	83,71	83,82
DMU14	**100**	**100**	83,05	65,09	90,03	72,52	76,91	76,73	68	58,02	73,34	61	55,81
DMU15	**100**	93,08	89,23	97,78	90,91	95,05	99,95	**100**	**100**	**100**	91,51	81,08	81,31
DMU16	**100**	97,86	96,41	**100**	97,13	99,63	**100**	**100**	99,29	**100**	97,24	83,55	83,8
DMU17	99,42	97,68	96,54	**100**	97,35	**100**	**100**	**100**	98,65	**100**	97,42	83,98	84,31
DMU18	**100**	99,81	98,78	99,21	99,11	**100**	98,72	**100**	98,28	98,29	99,2	82,96	83,15
DMU19	**100**	99,01	97,92	99,7	98,31	**100**	99,29	**100**	98,78	99,15	98,14	83,45	83,57
DMU20	99,91	**100**	98,96	99,04	99,4	**100**	98,64	**100**	98,03	98,03	**100**	82,66	83,06
DMU21	94,98	92,56	98,18	**100**	85,36	85,37	85,76	**100**	78,17	75,32	**100**	71,63	79,43
DMU22	**100**	**100**	98,9	99,1	99,38	**100**	98,74	**100**	98,12	98,1	**100**	82,67	83,08

Name	DMU01	DMU02	DMU03	DMU04	DMU06	DMU10	DMU11	DMU12	DMU15	DMU17	DMU21	DMU25	DMU32
DMU23	**100**	99,81	98,78	99,21	99,11	**100**	98,72	**100**	98,28	98,29	99,2	82,96	83,15
DMU24	**100**	99,01	97,92	99,7	98,31	**100**	99,29	**100**	98,78	99,15	98,14	83,45	83,57
DMU25	**100**	74,52	71,61	**100**	67,54	83,22	**100**	**100**	81,34	89,9	59,15	**100**	91,75
DMU26	**100**	98,28	97,02	**100**	97,58	**100**	**100**	**100**	97,87	99,24	96,63	84,58	84,62
DMU27	**100**	97,86	96,42	**100**	97,13	99,64	**100**	**100**	99,27	**100**	97,17	83,59	83,82
DMU28	90,91	66,67	40	37,04	58,82	47,62	**100**	90,91	34,48	40	38,46	71,43	66,67
DMU29	99,72	90,52	85,71	96,64	87,91	92,95	**100**	**100**	**100**	**100**	88,79	80,06	80,35
DMU30	99,72	90,52	85,71	96,64	87,91	92,95	**100**	**100**	**100**	**100**	88,79	80,06	80,35
DMU31	**100**	90,84	85,91	96,58	88,12	92,96	**100**	**100**	**100**	99,85	88,86	80,03	80,27
DMU32	67,19	44,56	50,13	**100**	50,82	81,07	**100**	**100**	74,96	**100**	57,31	**100**	**100**
DMU33	92,39	**100**	86,28	64,67	95,02	76,51	77,27	**100**	68,2	62,2	**100**	56,91	60,3
DMU34	**100**	99,81	98,78	99,21	99,11	**100**	98,72	**100**	98,28	98,29	99,2	82,96	83,15
DMU35	**100**	93,98	92,16	**100**	90,14	91,49	**100**	**100**	78,21	83,02	**100**	82,36	89,87
	26	9	1	16	2	**21**	**17**	**26**	**4**	**7**	**9**	**2**	**1**

Appendix D: Raw Data

Appendix D.1 Comparison of Raw Data According to Cross Efficiency Data

Raw Production Data for Total Production								
DMU		Processed Milk (ton)	Labor costs (TL/month)	Loss	Energy Costs (TL)	Production amount(ton)	Sales (TL/month)	1/Whey Protein
DMU 1	Jan,18	1430	825.956	1,1%	121.054 ₺	200	7273357	0,02
DMU 4	April,18	2150	827.692	2,7%	175.196 ₺	280	9830796	0,03
DMU 10	October,	2080	918.987	2,1%	256.259 ₺	260	9283677	0,03
DMU 11	Nov.,18	2090	917.343	1,0%	251.589 ₺	280	9871012	0,03
DMU 12	Dec.,18	2030	2.183.203	1,1%	224.698 ₺	280	9833408	0,07
Raw Production Data for White Cheese Production								
DMU 1	Jan,18	146	32180	0,11	6.243	23	73.259 ₺	0,17
DMU 9	Sept.18	4	36361	0,15	674	1	175.711 ₺	1,00
DMU 11	Nov. 18	14	36211	0,13	3.100	2	103.217 ₺	0,25
DMU 20	August	5	46661	0,12	1.154	1	151.720 ₺	1,00

Raw Production Data for Hellim Production									
DMU		Processed Milk (ton)	Labor costs (TL/month)	Loss	Energy Costs (TL)	Production amount(ton	Sales (TL/month)	1/Whey Protein
DMU 1	Jan,18	327	112630	0,15	20247	41	1.146.422 ₺	0,03
DMU 6	June,18	207	112918	0,23	25516	26	1.133.565 ₺	0,07
DMU 17	May,19	307	179439	0,11	64736	38	2.275.818 ₺	0,04