Mapping the dairy value chain in Western Macedonia Region

-Technical Report-

Dr. Ioannis E. Kaimakamis

April 2022

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1. Introduction

The dairy processing industry is a specific and challenging field for the Western Macedonia Prefecture (WM). This is mainly related to the fact that the main raw material (raw milk composed for only 13% of components and for 87% of water) is being transformed via a highly interrelated production processes into thousands of end products.

Often a byproduct of a production process of a certain product is an input for production of another product. For instance whey, which is a byproduct of among others cheese production, is an input for the production of various products, e.g. Infant Food and Ingredient products. This high complexity calls for a central and integral planning process that provides plans for the production of all products simultaneously.

Apart from the large number of products, efficient valorization of milk is, from an organizational point of view, additionally aggravated by the large number (28) of Small Operating Companies (OpCos) that form the company. Each OpCo in WM is responsible for all or some of the activities related to specific product groups and sometimes specific regions, i.e. production, inventory, distribution, marketing, sales and customer services. Each OpCo also has its own objectives that may not always lead to the best integral valorization of members´ milk, for the company as a whole. As in decoupled supply chains, in which added value can be gained if an integrated planning approach is achieved (Guajardo et al., 2013), an integrated planning approach is required to better valorize the milk which producing by farmers in WM.

To achieve maximum milk valorization- and to add value- a corporate Milk Valorization & Allocation (MVA) company must be created with a core business in the processing of the whey. The aim of this for us is “to ensure getting most value out of OpCos in WM, based on a geographical integral valorization point of view”. This creates an opportunity for valuable entrepreneurial discovery process.

2. Dairy supply chain in Western Macedonia

The improvement of diary supply chain can be attained in many ways, depending on the angle from which we look at it. For instance, looking from a food science (biotechnology) perspective, milk valorization can be improved through a better decomposition of raw milk into valuable ingredients (Gibson, 1991; Rattray and Jelen, 1996; Steijns, 2001). Looking from a product development or marketing perspective, milk valorization can be improved through new product developments or through the enlargement of market shares and new geographical markets (Biström and Nordström, 2002; Grunert and Valli, 2001). Looking from operations and planning perspective, improvement of logistics in various angles of a supply chain (Claassen and Van Beek, 1993; Vidal and Goetschalckx, 2001) can also contribute to a better valorization of members´ milk.

In the session of Entrepreneurial Discover Process (EDP), we focus on by-products valorization (whey) from the perspectives of food science, new product, logistics and business operation management.

The small size of the OpCos (dairies) and the number of actors and processes involved, defines the WM regional area almost as a complete dairy supply chain (see Figure 1.1). As can be seen, the core focus of this project is the by-products stream, but necessary input information related to supply (farm data) and demand (customer data) are also incorporated.

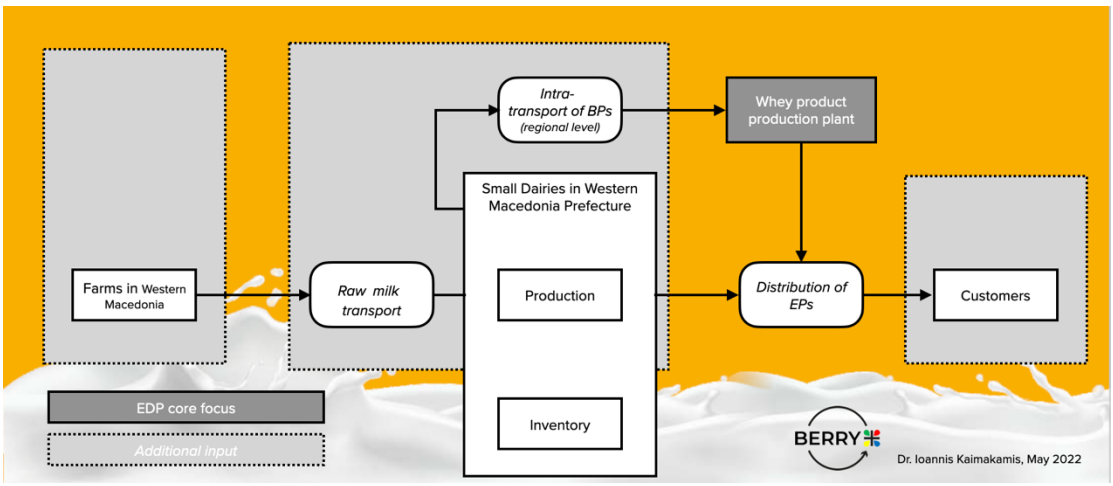

Figure 1.1 Dairy supply chain in Western Macedonia with indicated with EDP scope. *BPs= byproducts; Eps= end products*

By means of a workshop, we made the selection of the byproduct valorization project that should receive attention in this EDP session and that all together would provide the largest contribution to the improvement of Western Macedonia dairy value chain.

3. Raw milk production in WM Prefecture

The WM prefecture is one of the regions of Greece which composite from 4 regional units (Grevena, Kastoria, Kozani, Florina).

Table 1 Raw milk production (in tonnes) and number of farmers (2021)

	SHEEP MILK[1]	GOAT MILK[1]	COW MILK[2]	# OF FARMERS
GREECE	688.060	157.606	652.651	50.483
WM	48.886	12.675	25.247	2.811
%	**7,10**	**8,04**	**3,87**	**5,57**
GREVENA	8.343	3.613	5.157	584
KASTORIA	7.317	1.332	0	316
KOZANI	**21.236**	**5.534**	9.261	1.030
FLORINA	11.990	2.196	**10.829**	881

Source: Hellenic Agricultural Organisation Demeter
[1]80% of total production processed into different regional areas
[2]100% of total production processed into different regional areas

4. Cheese production in WM

Ironically, the most of the raw milk that produce the WM are not processed into the dairies which located in the area (see the table 1). This is a very big challenge for us.

Table 2: Cheese production (year 2019)

	SOFT CHEESE (FETA)	HARD CHEESE	BUTTER	WHEY CHEESE	CREAM
GREECE	101.502	31.234	2.131	12.805	5.897
WM[1]	2.557	355	3	176	16
%	**2,52**	**1,14**	**0,14**	**1,37**	**0,27**
GREVENA	**1.225**	158	2	95	0
KASTORIA	118	5	1	0	0
KOZANI	1.126	162	0	81	16

FLORINA	88	30	0	0	0

Source: Hellenic Statistical Authority [1]Operates approximately 28 small dairy plants

5. Mapping the dairy flows

The output of a dairy flow plan can then be used to create the operational production plans and discover gaps and more opportunities on the dairy value chain of WM.

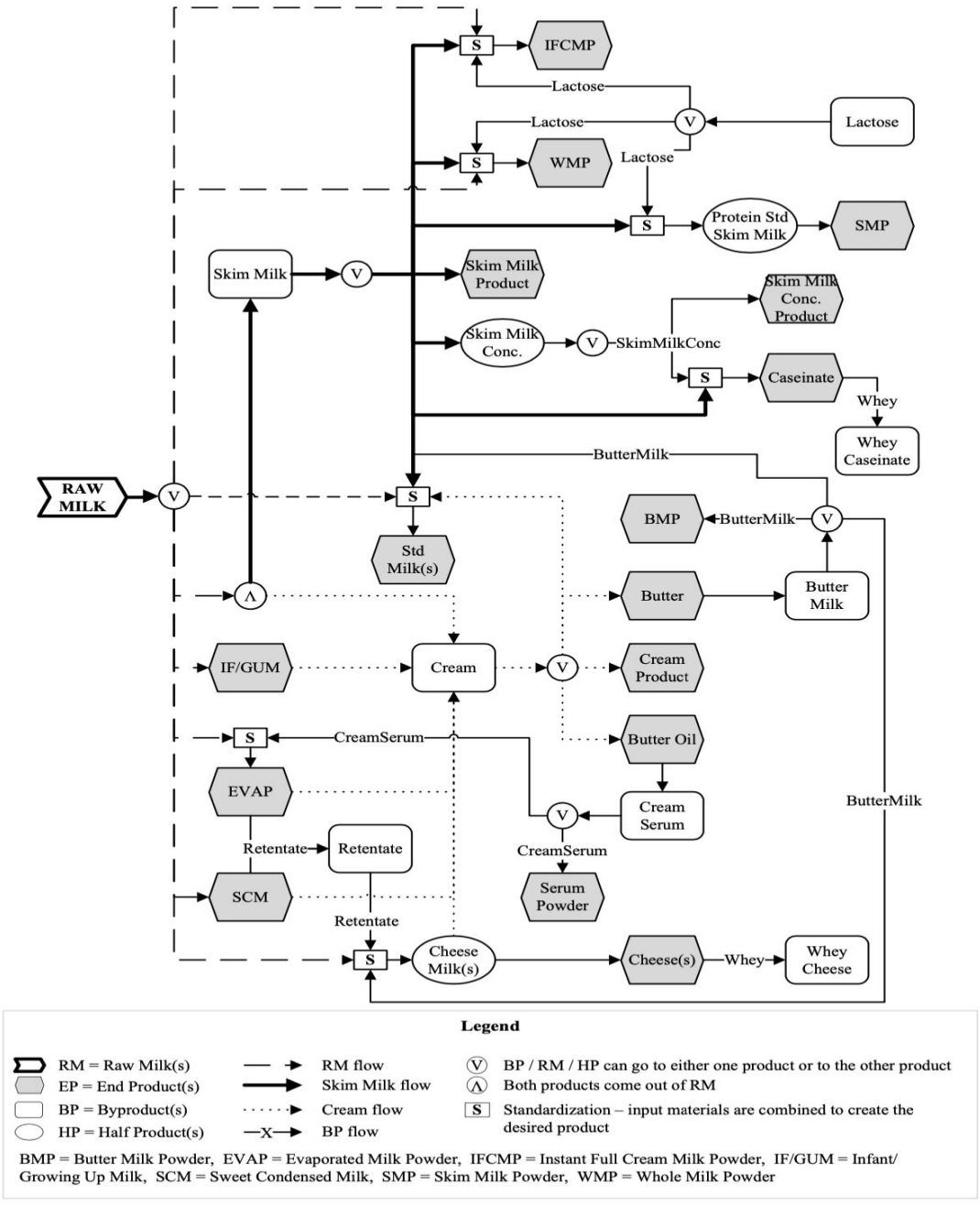

Figure 6.1 Dairy flows (based on Zimmermann 2001 and discussion with diaries experts)

The production of whey, its high environmental impact in WM, and its high nutritional content indicate that this byproduct is an important byproduct for which careful valorization is important for us.

At this stage we discover the opportunity and we search for more synergies in the area of research and entrepreneurship.

6. Dairy byproducts production in WM

The production of cheese results in volumes of byproducts, which are often not properly valorized in WM and as a result parts of this edible food are wasted. Recent studies of the Food and Agriculture Organization of the United Nations (Gustavsson et al., 2011) estimated that globally 40-50% of fruits and vegetables, 20% of meat and dairy, and 30% of fish are wasted. One of the main stages of the supply chain where food waste takes place is indeed processing (Parfitt et al., 2010). The need to more efficiently utilize food resources and the environmental impact of the disposal of byproducts induce scientists, producers and entrepreneurs to place more focus on the further processing of these byproducts.

7. Mapping the flows of whey based products

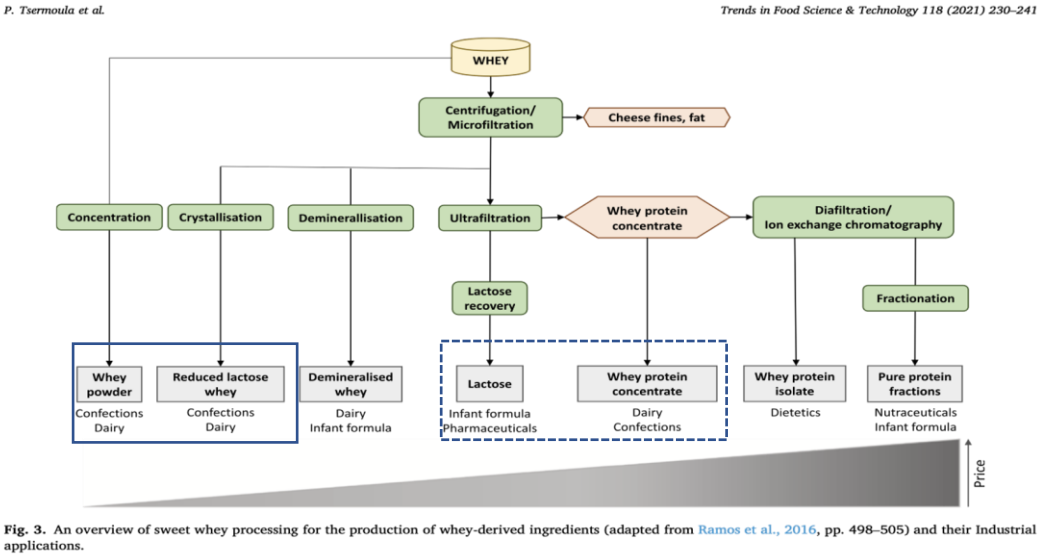

Fig. 3. An overview of sweet whey processing for the production of whey-derived ingredients (adapted from Ramos et al., 2016, pp. 498–505) and their Industrial applications.

Figure 7.1 Flow diagram of all whey products (based on Tsermoula et al. 2021)

8. The whey forward

The unprocessed whey originates from small cheese plants scattered around Western Macedonia Prefecture. Looking at the variances in whey pools, the most glaring difference is the types of cheese made. The whey produced from feta cheese (is commonly in the area of the WM) is preferred, as it is colorless and has a neutral flavor, and is sought after for products such as WPI and whey permeate derivatives.

For now, the way forward for many cheese and whey investments will be big cheese plants with more generic styles of cheese, such as mozzarella, and with whey processing capabilities planned, including derivatives and fractionation. But it won't be large-scale facilities, consolidators may step in to pool the remaining unrefined whey around the world, as Milk Specialties Global- MSG- (https://www.milkspecialties.com) has done in North America. But, it may be more reasonable for smaller cheese manufacturers from WM region to work together through various partnerships to capture the added whey value for their businesses.

9. Understanding the whey stream

Whey protein accounts for about 20% of the protein in milk, with casein accounting for the remaining 80%. When cheese is made, the casein and the milk fat form the bulk of the cheese, leaving liquid whey as a by-product. From 100kg of milk, you can make approximately 10kg of cheese, the remaining 90kg is liquid whey, the bulk (~90%) of which is water. Once the water is removed, you are left with about 5.5kg solids, comprising 4.2kg carbohydrates/sugars (lactose), 0.60 kg minerals and other components, and 0.6kg protein. So, in short, the good stuff whey protein is just 5.0% of milk solids. For the purposes of this report, we will generally be focused on the 5.5% solids left from cheese production referred to above.

The first add-value step of whey processing is to manufacture dry whey. One hundred kilograms of liquid whey yields nearly 5.5kg of dry whey powder, which comprises about 11% whey protein, 85% lactose plus minerals, and 4% moisture. The next level of liquid whey processing concentrates the proteins by using selective membranes to retain the proteins, while allowing the lactose and minerals to "permeate" thought the membrane. Whey protein concentrate (WPC) varies in

protein levels from 34% to 80%, and at the top end of the scale, whey protein isolate (WPI) contains a minimum of 90% protein. Just as whey is a by-product of cheese production, whey protein concentrate production results in a by-product, whey permeate, which is comprised mainly of lactose plus minerals with a small amount of protein. The whey-permeate yield from production of WPCs varies across the different whey products manufactured the higher the whey protein concentration, the more whey permeate is generated. Of 50kg whey dry solids, about 15.5kg of WPC 35 plus 34.5kg permeate can be produced, or about 6.9kg of WPC 80 plus 43.1kg of permeate. With modern-day WPI production using microfiltration, a high-fat WPC 70 product such as procream can be generated as by-product.

Estimation the total quantity of the whey produced in WM (base scenario)

- From 100 kgr of milk you can make approximately 22 kgr of feta cheese (soft)
- For 2.557 tons of feta cheese (see table 2) we need approximately 12.000 ton of raw milk (sheep and goat)
- From 100 kgr of milk you can make approximately 10 kgr of hard cheese
- For 355 tons of hard cheese (see table 2) we need approximately 3.500 ton of raw milk (sheep and goat)

Total amount of raw milk which is under processing 15.500 tons annually with seasonal patterns. The stream produce the follow products:

1. Cheese: 2.912 tons
2. Liquid whey: 12.500 tons (approximately)

At the next stage we use the liquid whey:

- Total quantity of the liquid whey: 12.500 tons
    - Which is,
        - Water: 11.250 tons (not for commercial use)
        - Solids: 680 tons (approximately)
            - 516 tons carbohydrates/ sugar (lactose)

- 75 tons minerals
- 89 tons whey proteins

Crude value of the whey in WM

European market

- 516 tons of lactose (price 735€/ ton^{-1})= 379.260€ annually
- 110 tons of whey powder concentrate 80% (price 4.450€/ ton^{-1})= 489.500€ annually

US market

- 516 tons of lactose (price 816€/ ton^{-1})= 421.056€ annually
- 110 tons of whey powder concentrate 80% (price 8.100€/ ton^{-1})= 891.000€ annually

The collection procedure of liquid whey from the production plants and dairies estimated as:

- 12.500 tons (price 40€/ ton)= 500.000€ annually

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Appendix

Whey supply chain mapping

Raw material	Key technologies	Products	Application	Key investments	Promotion	Policy	Partnerships	Remarks
Raw Milk	Centrifugation/ micro-filtration/ cheese equipment	Cheese/ whey	Food					
Whey	Concentration	Liquid whey concentrate	Animal feed	Whey handling equipment for concentrating and testing whey	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey	Concentration/ drying	Whey powder (SWP)	Animal feed/ food	Specialised drying (used in the food industry)	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey	Demineralisation/ fractionation	Demi-Whey/ Minerals/ Milk calcium minerals	Food/ IMF/ Pharma	Whey demineralization equipment	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey	Mechanical separation	WPC	Animal feed	Clarifiers and hydro soft feed system	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey	Ultrafiltration	Whey permeate	Animal feed/ food	Milk and whey ultrafiltration systems/ UF	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey permeate	Lactose process	Edible lactose/ De- lactose permeate	Animal feed/ food/IMF/pharma	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	Lactose can be made from whey permeate . The yield is about 65%lactose and 35%DLP (de-lactosed permeate).
Lactose	Lactose process	Edible/ Refined edible/ pharmaceutical grades	Food/ IMF/ Pharma	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Edible lactose	Lactose process/ refining	Pharmaceutical lactose	Pharma	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Edible lactose	Lactose process/ enzyme conversion	Galacto-oligosaccharides	IMF	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	Prebiotic used in early-life nutrition (ELN)
Edible lactose	Lactose process/ Biotech conversion	Human milk oligosaccharides	IMF	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey	Ultrafiltration	Whey protein concentrate (WPC) 35	Food/ sport nutrition/ clinical/ pharma/ food	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	High-fat WPC 50 and WPC 70 often known as procream
Whey	Ultrafiltration	Whey protein concentrate (WPC) 85	Food/ sport nutrition/ clinical/ pharma/ food	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey protein concentrate (WPC) 85	Hydrolysis	Hydrolysed whey protein concentrate	Food/ sport nutrition/ clinical/ pharma/ food	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey	Ultrafiltration/ fractionation	Lactalbumin/ β-lactalglobulin	IMF	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	
Whey	Ultrafiltration/ microfiltration	Whey protein isolate/ Pro cream WPC 70	Food/ sport nutrition/ clinical/ pharma/ food	UF/ reverse osmosis/ clarification/ chromatography/ nanofiltration/ evaporation	Sustainability/ circular economy/ environmental footprint/ health/ protein rich/ clean technology	RIS3 policy/ innovation/ environmental/ circular economy	Dairy cluster/ manufacturer/ food industry/ pharma industry/ feed industry	

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