

What pressure driven membrane processing has to do with butter milk and whey for sustainable income generation in India

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Abstract

Objectives: The present concept explores creation of multidimensional employment opportunities through application of membrane processing in the area of by-products utilization for dairy industry. Membrane filtration assisted utilization of whey and buttermilk not only provides a sustainable source of income but also finds helpful in providing means for food availability and nutritional security.

Methods/Statistical analysis: In this study, methodology has been remained dependent on the nature of food material, size of membrane pores and operating pressure. The nanofiltration technique which operates at a lower pressure than reverse osmosis is to separate water and monovalent salt materials from feed up to a considerable extent as per the required composition of end products. The business elements associated with Integrated Membrane Processing Centre for vibrant entrepreneurial activities find favour under the existing socio-economic situation.

Findings: The need to utilize whey and buttermilk in economic way for generation of income has been a long standing priority as far as dairy industry is to be concerned. Conventional methods of processing have resulted not only in poor quality of products but the ratio of input to output energy has remained unmanageably very high. Due to this reason these by-products have not been found suitability in their utilization creating severe problems of non-conservation of food solids, economic losses and ecological threats. On the other hand very high water content with less per cent of total solids, these by-products are very difficult to handle and require enough large space. In effluent treatment also these by-products further indicate higher incurred cost, longer period of neutralization time as well as use of more chemicals. The present study reveals that use of membrane filtration system has reduced all problems associated with conventional method of processing. Products prepared from membrane processing system ensure better profitability along with negligible wastage.

Application/Improvements: Visualizing existing circumstances of ever worsening employment problem, the application of selected congenial membranes for preparation of value added products is one of the best remedial measures. The establishment of Integrated Membrane Processing Centre (IMPC) is expected to be replicated in various potential regions considering the wider availability of whey and buttermilk.

Keywords: Income Generation, Whey, Buttermilk, Membrane Processing, Business Elements.

1. Introduction

Even after seven decades of independence, India has not achieved complete success in solving the basic problems of Indian economy. Ever growing population along with shrinking per capita land availability has witnessed widespread poverty and unemployment in India. The United Nations International Labor Organization (ILO) in its World Employment and Social Outlook report finds economic growth trend worsening and lagging behind in order to fulfill the employment requirement of India. There is prediction for rising unemployment, stagnancy in job creation and overall social inequality in spite of a series of human welfare program implemented for development and progress, the never ending vicious cycle of poverty, unemployment, hunger and malnutrition keeps on increasing unemployment enhancement results in poverty expansion.

A press release of International Food Policy Research Institute (IFPRI, USA) just before the World Food Day 2018, India i.e. home to the world's second largest population has scored 103 ranks out of 119 countries on the GHI (Global Hunger Index). India still lags behind in improving GHI status as the last year position was 100 out of 119 countries. A lower rank is an indicative to stagnant progress dominating mainly due to hunger and malnutrition (Table 1). With growing population and poverty, the prevailing status of better health and human welfare is affected due to critical problem of pollution also.

Table 1. India on the scale of Global Hunger Index (GHI)

Year	Total number of considered countries	India's rank	India's index score
2007	118	94	25.03
2008	120	98	23.70
2009	121	102	23.90
2010	122	105	24.10
2011	122	108	23.70
2012	120	106	22.90
2013	120	105	21.30
2014	120	99	17.80
2015	117	93	29.00
2016	118	97	28.50
2017	119	100	31.40
2018	119	103	31.10

Although India is holding prominent position in the world regarding production of millets, milk, rice, wheat, vegetables, fruits and other edible commodities, harvest and postharvest losses are the major concern areas on the way of food availability, nutritional security and employment. As per the Press Information Bureau, Govt. of India, Ministry of Food Processing Industries, India loses agriculture produce worth 92.651 billion USD annually. This is almost amounted to three times of yearly budget on agriculture. As far as milk business is to be concerned in India, whey and buttermilk are the leading by-products of immense value. These by-products are produced in huge quantity but remained completely unutilized making nutritional losses, economic depletion and ecological imbalance. The large chunk of unutilized whey come from *chhana*, *paneer* and *shrikhand* manufacturing instead of casein, cheese and Greek yoghurt making as in developed countries, similarly buttermilk is synonym to watery milky fluid obtained during making of *makkhan* instead of sweet buttermilk produced during churning of cream. The whole northern part of India is known as *paneer* region while *chhana* has a household status in entire eastern India even up to Bangladesh. *Shrikhand* making is the most popular dairy based enterprises of western and southern India. A milk product which utilizes the maximum amount of milk of India in its making is ghee i.e. 35% [1]. Nearly 90% of ghee is prepared by traditional method converting milk into curd, churning of curd into *makkhan* and heating of *makkhan* to ghee thus generating a large amount of buttermilk during churning operation.

Advent of innovative membrane filtration units based on sound engineering principles open a new vista of buttermilk and whey processing, conversion and value addition without changing phase of valuable materials. In entire world, the effectiveness of membrane processing has been proved and validated for diversified applications from water to fruit industry, paint to pharmaceutical industry, textile to wine industry, petroleum to milk industry, effluent treatment and waste disposal to solvent extraction, sugar industry to biotechnology etc [2-14]. On socio economic front there may be various possible approaches and schemes to minimize the extent of poverty through employment and income generation, but in this paper the focus will be mainly on effective, efficient and remunerative utilization of whey and buttermilk with the help of membrane filtration technology as never before conceptualized for India.

2. Why whey

In India, whey produced mainly in unorganized sector is not utilized appropriately. Whey is mostly thrown away as waste [15]. Besides providing nutrition and excellent functional properties whey and varieties of products obtained from it, are recognized as nutraceutical foods of multifaceted benefits (Table 2). The characteristic composition of whey depends on processing methods utilized during manufacturing of main products (Table 3). Whey may approximately contain 80% of lactose, 50% of mineral and 10% of protein and lipid portion of milk. Thus, whey represent nearly 47% of milk solids in it, hence its losses simply implication to the wastage of food [16]. India cannot afford such a situation of food wastage due to burgeoning problems of food inadequacy and nutritional insecurity. Not only in India but in all over the world the popularity of fermented and acidified dairy products is increasing tremendously. Even in USA, production of Greek yoghurt has been increased from 1-2% to 40% from 2004 to 2015. Each kg of Greek yoghurt production gives approximately 3 kg of acid whey production [17].

Table 2. Functional Properties, Food Quality, Health Benefits of Whey and Whey based Products [18-26]

Functional Properties	Food Quality	Health Benefits	Whey based products
Water binding	High protein efficiency ratio (3.6)	Anti diabetic and insulotropic, Dilipidemia prevention, Neuroprotective, Phenylketonuria management, Anti cancer,	Whey powder, Whey protein concentrates, Whey Beverages, Whey concentrates, Undenatured whey concentrate,
Solubility			
Emulsification	Net protein utilization (95)	Provide muscle strength, Improved immune system, Muscle synthesis, Enhanced performance / endurance,	Organic acids, Hydrolyzed whey protein, Infant foods, Salt substitutes, Personnel care products,
Foaming	Biological Value (104)	More favorable body composition, Antimicrobial	Lactose, Whey protein isolates, Peptides with antioxidant activity, Fermented whey products
Gelling			

Food has its own economic value too. The persisting scenario of very poor utilization of whey in Indian perspective is nothing but a drain of food resource also. Whey contains approximately 80 to 90% of whey protein of milk. Whey proteins are matchless due to its nutritional and functional characteristics. The recent scientific validations for therapeutic properties associated with whey compel the milk industry to utilize it purposefully for curbing the threats of chronic diseases (Table 2). Whey proteins have emerged as the life line of sports, nutraceuticals and pharmaceuticals formulations [21].

Table 3. Average composition of whey obtained from various sources [27-29]

S. No.	Constituents	Chakka whey	Paneer whey	Casein whey	Cheese whey
1.	Moisture	93.43	93.64	93.52	93.40
2.	Fat	0.20	0.25	0.13	0.15
3.	Protein	0.65	0.35	0.77	0.57
4.	Lactose	4.90	5.15	5.0	4.70
5.	Ash	0.76	0.61	0.50	0.65
6.	Acidity	0.70	0.38	0.30	0.36

Whey contains rich organic elements in it. The BOD and COD of whey obtaining from various sources may be in range of 30,000 to 50,000 mg/ l and 60,000 to 80,000 mg/ l respectively [30]. Due to the presence of organic substances, the effluent treatment cost containing whey remains very high in general jeopardizing the overall economy of waste treatment. The unwise disposal of whey may lead to local ecological imbalance.

Emerging environmental standards and regulations bring severe punishment for any disturbance in existing aqua, fauna and flora set up which also compel milk products manufacturer to a single option i.e. effective utilization of whey. The typical characteristics of whey itself encourages for formulation of a varieties of products. Congenial buffering capacity of whey facilitates better survival and growth of probiotic bacteria in intestine. The presence of whey components enhance nutritional, sensory and functional attributes of prepared products. Utilization of produced whey therefore is necessary for diversification of dairy plants and products manufacturing units for its sustainable survival.

3. Incomparable advantages of membrane filtration in whey processing

The ever increasing production of *paneer*, *chhana*, *shrikhand* and cheese generates huge amount of whey. As per the prevailing practices majority of whey produced in India is not utilized at all and being consider as a waste [31]. Whey is a liquid. For a liquid, membrane processing under congenial operating pressure is able to separate, purify, concentrate and fractionate desired substances on the basis of size from undesired one. The various conventional whey processing methods for manufacturing of different products have been found to be uneconomical due to intense energy requirement [32]. The emerging concept of stringent cost minimization along with better utilization of whey seems opportunity only in membrane processing [18, 33]. In present scenario membrane filtration is the best available option for whey handling and its conversion into high commercial products. The most widely used membrane separation technique for whey is ultrafiltration. In ultrafiltration membrane, present fat and protein get concentrated while lactose, lactic acid and soluble ash content are permeated out. Removal of fat in pretreatment provides a vast opportunity to membrane filtration for making of a series of concentrated protein products (Table 2). The advantage of ultrafiltration is that permeate stream gets sterile due to retention of microorganisms. Integrated application of different membrane processes was experimented for economic cheese production [34]. Concentration of whey protein was achieved by ultrafiltration, whereas ultrafiltration permeates were treated successfully by nanofiltration to restrict 0.1 to 0.3% lactose in permeate.

Presence of minerals in initial whey brings considerable impurities and quality deterioration when whey is converted into value added commercial products. Earlier the process of demineralization as per the need of ultra purified or extra grade products was not so effective. With the advent of nanofiltration technique more and more purified products can be easily obtained. The whey portion contains very high percentage of water which can also be concentrated with the help of suitable reverse osmosis process. But, nanofiltration is very suitable to whey treatment providing concentration and demineralization simultaneously. According to the nature of end products, pretreatments of whey with membrane filtration or with other processing methods can further enhance product quality and process efficiency in manifold ways. The most effective and locally available trend of making dairy and food materials free from microorganisms is heat treatment, but whey is ultra heat sensitive, even slightest thermal intensity is bound to result in severe quality deterioration. The technique of microfiltration is capable to remove bacteria from whey considerably with minimum or negligible quality damage [10].

4. Buttermilk and membrane processing

In India, a dairy product which utilizes the maximum amount of produced milk is ghee. For higher keeping quality and extraordinary sensory properties ghee is mainly prepared from *desi* butter also known widely as *Makkhan*. *Makkhan* buttermilk is produced as an intermediate product. Buttermilk is also produced in commercial dairy plants when cream is converted into butter. This aqueous phase derived as a by-product during *Makkhan* or butter making process is rich in milk fat globule membrane portions as well as all water soluble material present in milk. Buttermilk is popularly known as *chach* or *mattha*. Buttermilk has wide acceptability as a natural product. The popularity of buttermilk has been remained maintained to all over the country nearly in all seasons. Buttermilk is traditionally known as *Mor* in Tamil, *Mooruo* in Malayalam, *majjige* in kannada, *Chhash* (Gujarat & MP), *Mattha* (UP & Delhi), *Tark* (Maharashtra), *Ghol* (Bengal) [35].

Now - a – days a sustainable market of different variants of buttermilk is available particular in urban areas. As far as the vast area of Indian subcontinent is to be concerned, there are three types of buttermilk [36]-

1. Sweet cream buttermilk: obtained by churning of fresh cream with no or little developed acidity
2. Sour buttermilk: obtained by churning of naturally sour milk, *dahi*, cream
3. *Desi* buttermilk: obtained by churning of curd

Buttermilk has a lot of similarities to skim milk. Presently only sweet cream buttermilk produced in organized dairy plant is having its judicious uses, that too in restricted quantity. All these types of buttermilk contain nearly the same compositional total solids % (9.1 to 10.25), fat % (0.1 to 1.33), protein % (3.05 to 3.73), lactose % (4.2 to 4.81) and ash % (0.681 to 0.75). Sour buttermilk was observed to have higher acidity more than 0.15% and even as high as 1.0%. Buttermilk in different forms is not only utilized as thirst quenching, digestive, delicious refreshing drink but also in preparation of various nutritious culinary items (Table 4). Beside higher acidity there are similarities between buttermilk and whey also. In a compatible combination, research workers [37] utilized *paneer* whey up to 50% successfully for manufacturing of cultured buttermilk.

Buttermilk has observed to be more nutritious and full of therapeutic value as it contains health beneficial microorganisms. The quality of buttermilk is characterized for exclusively containing of milk fat globule membrane. The ruptured milk fat globule membrane containing lipid fraction and associated proteins in buttermilk improves nutrition and functionality of it considerably. More than 80% of buttermilk proteins are major milk proteins i.e. casein and whey proteins. Nearly 20% of buttermilk proteins come from milk fat globule membrane [38]. The concentration of phospholipids determines the significance of end products obtained from buttermilk. In an experiment [39] a rich phospholipids powder from whey buttermilk was prepared with the help of ultrafiltration, difiltration, and spray drying and subsequent supercritical extraction. The lipid portion of developed powder was found to contain 61% of phospholipids. The use of ultrafiltration for concentration of sweet cream buttermilk was found the most attractive when compared with concentration by reverse osmosis and evaporation [40]. In a research addition of ultra-filtered buttermilk to cheese milk at the rate of 5% produced softer cheese with improved body and texture and increased yield than control [41]. In preparation of mozzarella cheese also 5 % ultrafiltrate of buttermilk was experimented successfully [42].

Table 4. Significance of buttermilk [32, 37, 43, 44]

Applications of buttermilk	Functional properties provided by buttermilk	Therapeutic properties of buttermilk
For nutrition	Foaming	Anti ulcer remedies
As flavor enhancer	Emulsification	Prevention in nervous disorder
Prevention for spattering	Viscosity	Lowers blood cholesterol level
Baking improver	Protein solubility	Avoid dehydration
Formulation of milk products	Water holding	Anti-carcinogenic
	Product stability	Antibacterial
	Gel formation	Indigestion and Anti constipation
		Anti swelling
		Obesity prevention
		For treatment of hemorrhoids

5. Grassroots empowerment through Integrated Membrane Processing Centre (IMPC)

Establishment of membrane processing centre will create huge employment opportunities in

1. Procurement of whey and buttermilk
2. Manufacturing of intermediate and finished products
3. Marketing of prepared products

With growing health awareness regarding whey and buttermilk products, a sound market is expected to grow considerably over coming years. The entrepreneurship associated with safe handling and supply of quality whey and buttermilk in adequate quantity can also generate huge profit. Buttermilk and whey are very suitable for processing through membrane filtration because these are fluids consisting less amount of fat and protein and more of water, lactose, minerals and whey protein molecules from milk.

Buttermilk and whey are by-products of dairy industry. They are secondary products not the intended products. These by-products become raw material for others industry if obtained from integrated membrane system intelligently. At integrated membrane processing centre with all four major membrane variant, a series of buttermilk and whey based products can be prepared. In principle, the process of separation remains nearly the same for all types of membrane. For filtration, the fluid material either whey or buttermilk is being pumped over a membrane under specific operating condition which causes fractionation at the molecular level.

Factors affecting operation of membrane processing units-

1. Feed - liquid characteristics
2. Membrane - physical, chemical and configurational matrix
3. Operational conditions - pressure, temperature, flux, feed velocity, Turbulence and cleaning methodology

As per the requirement of retentate and permeate, selection of suitable membrane material is carried out (Table 5). Organic membranes are flexible, cheaper and provide higher packing density in comparison to inorganic one. Organic membranes have its limitation against a wide temperature range, pH and operating pressure. Because of sensitivity to various chemical cleaning substances these types of membranes may have some limitation in operation.

Table 5. Characteristics of membrane

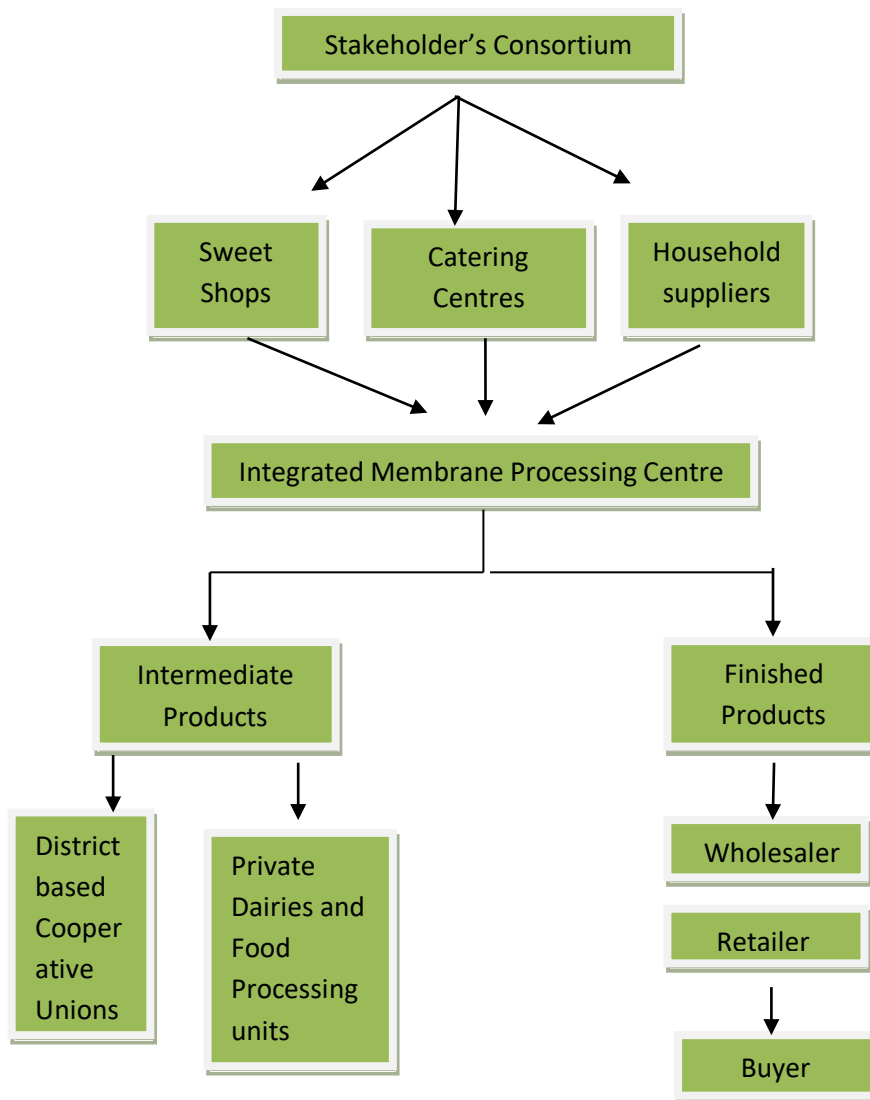
Types	Pore Size (µm)	Retentate	Permeate	Pressure (bar)	Material Evolution	Module
Microfiltration	10 ⁻¹ - 10	Fat globule, bacteria, spores and casein micelles	Lactose, minerals, whey proteins, water	0.1 -1.0	1 st generation	Plate and Frame
Ultrafiltration	10 ⁻² – 10 ⁻¹	Whey Proteins+ above	Lactose, minerals and water	0.5 - 5	2 nd generation	Tubular
Nanofiltration	10 ⁻³ – 10 ⁻²	Lactose, Divalent ions+ above	Monovalent ions, water	5 -30	3 rd generation	Spiral-wound
Reverse Osmosis	10 ⁻⁴ – 10 ⁻³	Monovalent ions +above	Water	20 – 100	Hybrid processes	Hollow-fiber

By using either an appropriate membrane system or a system of integrated membranes, the opportunity for adding value to whey and buttermilk as commercial products may be achieved. The commercial production of individual milk component is now become possible with pressure driven membrane filtration techniques. Business Elements associated to IMPC (Figure 1).

1. Finance: subsidized, nearly complete assistance from banks, state & central govt.
2. Equipment: established manufacturers and suppliers with training facility
3. Manpower: adequate availability
4. Materials: available at cheaper rate as by products
5. Site: community hall, premises on rent basis, govt. approved industrial location
6. Marketing: assured for intermediates and finished products. Even supply of drink and health beverages under govt. mid-day meal scheme, hospitals, mess, etc. besides in open market.

Intermediate products of whey and buttermilk will require further processing before they reach to ultimate consumers. These products will have sale opportunities to various processing plants bigger in nature such as dairy cooperative units and private ventures equipped with multistage drying facility. Fat free sterile demineralized whey liquid, defatted whey protein concentrates, protein free whey liquid, demineralized buttermilk, nonfat buttermilk concentrates, delactose buttermilk products etc. can be regular products for sale to such organization from IMPC. After passing through various handling and processing stages at IMPC, varieties of beverages of whey and buttermilk may be prepared under the category of finished products for direct distribution and sale. Preparation of *kadi*, *rayeta*, *rasam*, *dahibade*; *golgappe pani* and other culinary items preferably require acidic materials. Buttermilk, whey and various products obtained from it of desired sourness may be very popular and quite acceptable in this regard. The entrepreneurial activities based on membrane filtration system will fail if remain unsuccessful to meet its responsibility to the stakeholders of the organization including of suppliers, distributors and consumers.

Figure 1. Concept of a set of vibrant entrepreneurial activities at Integrated Membrane Processing Centre (IMPC)



Integrated membrane processing centers may have their location either in association with village cooperative societies, milk collection units, chilling units, block headquarter, village community centre or in independent way. These centers can generate ample opportunities of productive jobs, as human resource is the major asset and it is ever available in remote areas. There are also various upcoming isolated industrial areas under the government patronage for establishment of entrepreneur activity at a nominal subsidized rate. In urban areas also a supply chain for whey and buttermilk from production point to processing centre can be established as numerous shops and sweetmeat sale points are engaged in manufacturing of *paneer*, *chhana*, *shrikhand* and cheese. For ensuring a strict quality compliance of standards for finished products, the raw material quality must be of high grade. Creation of effective handling and processing facility near to production point avoids possibility of much deterioration in whey and buttermilk quality. Transportation and handling of whey and buttermilk is cost intensive because of high percentage of water in it. The cost involved in bringing raw materials to the point of processing is going to be escalated if bulk is not going to be removed at place near to production site. Enough emphasis must be given on identification of cluster areas on the basis of route facility. This will bring:

1. Assured supply of quality raw materials
2. Consistent availability of raw materials
3. Minimization of collection cost

Integrated membrane processing centre is an establishment where whey and buttermilk are collected, handled safely, value added as per specific processing with suitable membrane plant and marketed for sustainable economy. The installation capacity, types of membrane filtration plant, associated equipment, location and arrangements of equipment in premises of membrane processing centre, all depend on the nature and amount of raw material going to be handled and types of products decided to manufacture. Membrane processing greatly helps to reduce waste and to make diversified products by increasing the shelf life of whey and buttermilk that cannot be immediately consumed just after the production with due profitability. Handling and processing of procured whey and buttermilk in integrated membrane processing centre bring all associated benefits of membrane technology –

1. concentration, purification and fractionation at a very low operating temperature,
2. integration of different membrane facilitates capacity augmentation,
3. value added products can prepare without any addition of chemical,
4. minimal energy requirements,
5. low cost of installation and operation,
6. easy in maintenance,
7. better shelf life of prepared products due to considerable removal of microbes,
8. better protection in natural, sensory, chemical and nutritional quality of products,
9. separation of component in its native state,
10. removal of water in product making process reduces handling and transportation cost

6. Conclusions

The noble commitment of Indian society to make leaps and bounds progress in the matter of economy is low sided due to increase in the number of unemployed masses. Unemployment and poverty form a vicious reciprocal relationship each helping the other to add miseries of many Indians in terms of food unavailability and nutritional insecurity. There is an urgent need for creation of favorable environment and means to generate sustainable regular income. Considering the unique characteristics of whey and buttermilk with its abundant availability at negligible cost, the present scenario of huge losses due to lack of proper collection, safe handling and inadequate processing can be minimized up to considerable extent. The vast potential of pressure driven membrane filtration techniques related to processing of whey and buttermilk, if utilize effectively, may bring the radical changes in social development and economic growth.

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