EVALUATION OF MICROFILTRATION OF TENDER COCONUT WATER

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR-679573, MALAPPURAM, KERALA, INDIA

2022

DECLARATION

I hereby declare that this thesis entitled "**Evaluation of microfiltration of tender coconut water**" is a *bonafide* record or research work done by us during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "**Evaluation of microfiltration of tender coconut water**" is a bonafide record of research work done independently by **Ms. Aiswarya E S (2019-06-001), Ajsar Muhammed Rafeeq (2019-06-003), Arjun Raj M P (2019-06-004), Darshana M Nair (2019-06-005)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship.

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DEDICATED TO THE

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LIST OF SYMBOLS AND ABBREVIATIONS

MF	:	Microfiltration
PAN	:	Polyacrylonitrile
PS	:	Polysulfone
PE	:	polyethylene
UF	:	Ultrafiltration
NF	:	Nanofiltration
RO	:	Reverse osmosis
OD	:	Osmotic distillation
MD	:	Membrane distillation
EPS	:	Extracellular polymeric substances
HPP	:	High-pressure processing
HTST	:	High-temperature short time
SEM-EDS	:	Scanning electron microscope energy dispersive spectrometer
TPC	:	Total plate count
TCW	:	Tender coconut water
TDS	:	Total dissolved solid
COD	:	Chemical oxygen demand
TAA	:	Total antioxidant activity
Fig.	:	Figure

HMF	:	Hydroxymethylfurfural
POD	:	Peroxidase
PPO	:	Polyphenol oxidase (PPO)
PS	:	Polysulphone
I.U	:	International Unit
ppm	:	Parts per million
MWCO	:	Molecular weight cut-off
KDa	:	Kilodalton
RPM	:	Revolution per minute
dv	:	Cumulative volume
dt	:	Cumulative time
TSS	:	Total soluble solids
RP-HPLC	:	Reversed Phase -High Performance Liquid Chromatography
CFU	:	Colony forming units
TMP	:	Transmembrane pressure
LPH	:	Litre per hour
L *	:	Lightness or darkness
a *	:	Greenness or redness
b *	:	Blueness or yellowness
°	:	Degree
mL	:	millilitre
Kg	:	Kilogram

INTRODUCTION

CHAPTER I

INTRODUCTION

Coconut (*Cocos nucifera* L.) is an important fruit in the tropical regions. Tender coconut water is consumed as a refreshing drink because of its nutritional and therapeutic properties. The electrolyte and mineral balance makes tender coconut water suitable as a sports drink. However, it is very sensitive to deterioration and the water is un suitable for drinking after a day or so due to external contamination by microorganisms and oxidation because of which it loses most of its sensory and nutritional characteristics .Commercially available canned coconut water is given a high-temperature/short-time thermal treatment. Although the shelf life of thermally processed tender coconut water is long, thermal processing tends to decrease the nutrient content and completely destroys its natural flavour unlike non-thermal techniques. This severely limits the marketability of the product. Today's consumers are looking for natural products which are not adversely modified while providing targeted benefits. selecting technological processes to preserve the natural whole some properties of the coconut water still remain a challenge.

Tender coconut water (TCW) has a therapeutic effect, containing various nutrients such as minerals, vitamins, antioxidants, amino acids, enzymes, and growth hormones. Recent studies have shown that TCW is rich in L-arginine, a free form amino acid, and vitamin C, which can prevent heart disease and lipid peroxidation. In addition, TCW also contains various important compounds for the body, such as magnesium, potassium, calcium, selenium, methionine, zinc, iodine, manganese, boron, molybdenum and phytohormone such as auxin, cytokines, gibberellins. L-arginine can be used for the therapy and reduce the effects of heavy metal poisoning. Water content in a tender coconut of 5-7 months of age is about 500-750mL and depends on the maturity and varieties of coconut. TCW is the most nutritious healthy drink from coconut tree, is a natural isotonic drink that has content similar to our body's blood plasma. The content of macro and micronutrients

found in tender coconut water can lower lipids, protect the heart and liver. The content of nutrients of TCW is influenced by the age of fruit maturity, soil nutrient content and environmental conditions. Coconut water is called a natural isotonic drink because of the electrolyte content such as sodium and potassium contained in it. TCW can be used as ready to drink food product having natural health beneficial nutrients.

Microfiltration (MF) is a pressure-driven separation process, which is widely used in concentrating, purifying, or separating macromolecules, colloids, and suspended particles from solution. MF membranes typically have nominal pore sizes on the order of 0.1–1.0μm. MF processing is widely used in the food industry for applications such as wine, juice, and beer clarification, for wastewater treatment, and plasma separation from blood for therapeutic and commercial uses.

Polyacrylonitrile (PAN) is used to prepare microfiltration membranes and the average pore diameter is 0.1micron. The hollow fibres are hydrophilic. Inner diameter of hollow fibres is 0.7mm and outer diameter 1.3mm. Length of each fibre is 16cm. Total 80 numbers of such fibres are packed in a S" ID PVC pipe. Potting is done using resin. Thus, the effective membrane surface area of this cartridge is 280cm. Appropriate chemical treatment is carried out to reduce the pore size of the membranes and we can supply 70,000, 35,000, 20,000, 7,000 and 1,000 molecular weights cut off of hollow fibre cartridges. These cartridges are replaceable. One can fit several such cartridges of various molecular weight cut off (one at a time).

The juices are rich in various minerals, vitamins, and other nutrients. To process the juices and their clarification and/or concentration is required. The membranes are being used for these purposes. These processes are preferred over others because of high efficiency and low temperature. Membranes and their characteristics have been discussed in brief for knowing suitability of membranes for fruit and vegetable juices. Membrane separation is low temperature process in which the organoleptic quality of the juice is almost retained. The major fruit and vegetable juices using membrane processes are including the Reverse osmosis studies for concentration of orange juice, Carrot juice, and Grape juice. Microfiltration is used for clarification of juices of mosambi juice, apple juice,

pineapple juice, and kiwifruit juice. The various optimized parameters in membranes studies are pH, TAA, TSS, and AIS. Membrane separation is also used for used to remove bacteria from skimmed milk during the production of ultra clean milks, or for fractionation of the skimmed milk into a casein rich retentate and a milk serum devoid of casein.

This study aims to evaluate the physiochemical properties of tender coconut water samples treated at 5psi, 10psi and 15psi transmembrane pressure respectively and further analyse the effects on shelf life at different storage periods. The objectives are to optimize the process parameters for the membrane separation process of tender coconut water and to evaluate the shelf life of membrane separated tender coconut water.

REVIEW OF LITERATURE

CHAPTER II
REVIEW OF LITERATURE

This chapter briefly discusses the tender coconut water and its composition, importance of tender coconut water and its utilisation in the industry. The variables which decide the quality parameters and functional properties relevant to the microfiltration of tender coconut water also been reviewed and discussed.

2.1. TENDER COCONUT

Coconut (*Cocos nucifera* L.) popularly known as "Tree of life", is one of the most useful trees in the world. Tender coconut (7 to 8 months old maturity) is valued both for its sweet water, which is a refreshing drink and the delicious gelatinous meat (kernel). The water of tender coconut, technically the liquid endosperm, is the most nutritious whole some beverage that nature has provided for people of the tropics and is consumed fresh, largely because, once exposed to air and warm temperatures, it rapidly deteriorates. In addition, sterilizing the water using high temperature and short-time pasteurization destroys some of the nutrients and the entire flavour. Chemical composition and volume of the coconut water change during maturation (Jayalakshmi *et al.,* 1986, Shamina and John 2004). The reports of (Rao *et al.*, 2008) indicate that quality and quantity of coconut water as well as consumer acceptability of tender nut is more after 7 months of maturity.

Coconut water is a liquid endosperm, which accounts for approximately 25% by weight of the whole nut. It is a drink with somewhat mildly sweet and acidic flavour (pH 5.6), the color-less clear liquid inside the young green nuts, contains total solids of around 5% by weight. In natural form, the liquid endosperm is present in a hermetic cavity and is sterile in nature. Increased awareness among consumers regarding the unfavourable health effect of artificially carbonated beverages has led to high demand for processed coconut water with fresh like properties but with extended shelf life in bottles. The coconut water is the best alternative to athletic drink because of its low calorie (17.4 kcal/100 g). It contains minerals, amino acids,

phytohormones and beneficial bioactive compounds, such as vitamin-C, vitamin B, potassium, calcium, magnesium, sodium, glutamic acid, lysine, arginine, alanine, cytokinin, etc. (Naik and Rawson, 2020).

The bulky nature of the tender coconut and its tendency to undergo biochemical changes and spoilage after harvest are constraints in the popularization and marketing of tender coconut in natural form in areas where coconut is not grown. Although technologies are available for the processing of tender coconut water and matured water into packed soft drinks, consumer preference is for the natural taste of tender coconut. The increasing demand for natural drinks necessitated the urgency of making available, tender coconut water without spoilage and losing its inherent qualities. It is seen that tender coconut cannot be stored for more than one week at room temperature due to shrinkage and discoloration of skin, fall of perianth and fungal attack on the soft perianth region. study conducted in Sri Lanka revealed that the quality of tender king coconut could be maintained for few weeks when a whole nut was wrapped with cling film and stored at 14–15°C (Ranasinghe *et al.,* 1999).

Wijeratnam *et al*. (2006) conducted studies to facilitate low temperature storage and distribution of fresh king coconut, *Cocos nucifera* var. *auranta* and observed that nuts respond best to a dip treatment in wax formulation, when stored at 13.5°C for 28 days while nuts stored at 28 ± 2°C, showed complete deterioration after 7 days. storage of minimally processed tender coconut under refrigerated condition and transportation to distant places is becoming popular. But published reports are not available on the quality aspects of stored tender nuts. In this study the shelf-life of tender coconut was evaluated based on the variation in the quality parameters under different storage conditions.

2.1.1. Varieties

2.1.1.1. Cultivars

- West Coast Tall
- Lakshadweep Ordinary (Chandrakalpa)
- Philippines Ordinary (Kerachandra)

- Andaman Ordinary
- Java
- Cochin China
- Kappadam
- Komadan
- Karasagara
- Kalaparaksha
- Kalpadhenu
- Kalpaprathibha
- Kalpamithra

2.1.1.2. Hybrid

- Lakshaganga (Lakshadweep Ordinary x Gangabondam)
- Anandaganga (Andaman x Gangabondam)
- Keraganga (West coast tall x Gangbondam)
- Kerasankara (West Coast Tall x Chowghat Orange Dwarf)
- Chandrasankara (Chowghta Orange Dwarf x West Coast Tall)
- Kerasree (West Coast Tall x Malayan Yellow Dwarf)
- Kerasoubaghya (WCT X SSA)
- Chandralaksha (Lakshadweep Ordinary x Chowghat Orange Dwarf)

Source: KAU Agri info tech portal (2020)

2.1.2 Importance of tender coconut water

Tender coconut water has a therapeutic effect. Containing various nutrients such as minerals, vitamins, antioxidants, amino acids, enzymes, and growth hormones. Recent studies have shown that TCW is rich in L-arginine, a free form amino acid, and vitamin C, which can prevent heart disease and lipid peroxidation.

Also, TCW also contains various important compounds for the body, such as magnesium, potassium, calcium, selenium, methionine, zinc, iodine, manganese, boron, molybdenum and phytohormone such as auxin, cytokines, gibberellin. L-arginine can be used for the therapy and reduce the effects of heavy metal poisoning.

Treatment with L-arginine was able to increase GPx activity in mice exposed to plumbum (Pb). Cytokinin is a potent antioxidant against free radical-induced cell damage. Selenium is one of the micronutrients that form the GPx enzyme. Methionine is an amino acid containing sulfur that can be used as a source of thiols and plays a role in the synthesis of glutathione. The water content in a tender coconut of 5-7 months of age is about 500-750mL and depends on the maturity and varieties of coconut (Zulaikhah, 2019).

Priya and Ramaswamy (2014) reported the typical nutrient, Physico-chemical composition, and vitamin content present in the tender coconut water (Tables 2.2, 2.3 and
2.4).

Table 2.1 Nutritional composition of Tender coconut water

Component	**Types of Green Coconut**	
Components	***Wulung***	**Ordinary**
Vitamin C (Ascorbic acid) (mg/L)	32.50	32.50
Amino acid (µg/mL)		
- L- Aspartic	115.60	30.81
- L-Glutamic	56.65	28.90
- L- Glutamine	<0.05	6.32
- L-Threonine	25.15	13.40
- L-Glycine	19.01	16.08
- L-Arginine	12.68	12.63
- L-Alanine	22.18	22.97
- L-Tyrosine	23.57	9.95

- L-Tryptophan + L Methionnine	<0.13	235.22
- L-Valine	13.27	11.83
- L-Phenylalanine	12.68	8.80
- L-Isoleucine	10.10	11.48
- L-Leucine -	19.61	17.80
- L-Lysine -	23.77	26.22
- L-Histidine + Serine	47.34	26.41
Mineral (mg/Kg)		
- Cu (Copper)	<0.02	0.40
- Fe (Iron)	6.00	0.39
-mg (Magnesium)	146.16	74.24
- Mn (Manganese)	0.23	2.50
- Zn (Zinc)	2.20	0.83
- Na (sodium)	560.03	24.22
- K (Potassium)	6.31	2908.46
- P (Phosphor)	8.76	94.43

source: Zulaikhah, ST. 2019. Health benefits of tender coconut water (TCW). *Int. J. Pharmaceutical Sci. and Res,* 10(2

Table 2.2 Nutrient composition of tender coconut water

Components	Percentage
Water	95.5
Protein	0.1
Fat	<0.1
Mineral matter	0.4
Carbohydrate	4.0
Calcium	0.02
Phosphorous	<0.01
Iron in 100mL	0.5mg

Table 2.3 Physico-chemical and chemical composition of coconut water at different stages of maturity

Quality parameters	Maturity stage	
	7-8 months	**8-9 months**
soluble solids(°Brix)	5.08	0.64
pH	4.83	5.29
Glucose(g/100mL)	2.4	2.9
Fructose(g/100mL)	2.1	2.5
Sucrose(g/100mL)	-	0.4
Total sugar (g/100mL)	5.0	6.3
Potassium (µg/100mL)	198.7	215.8
Calcium (µg/100mL)	14.5	11.5
Magnesium (µg/100mL)	4.6	5.1
Chloride(µg/100mL)	144.6	157.4

Table 2.4 Vitamin content of coconut water

Vitamins	Value
Nicotinic acid	0.64µg/mL
Pantothenic acid	0.52µg/mL
Biotin	0.02µg/mL
Riboflavin	<0.01µg/mL
Folic acid	0.003µg/mL
Thiamine	Traces
Pyridoxine	Traces

Source- Priya, S.R. and Ramaswamy, L. 2014.

2.2 FACTORS AFFECTING SPOILAGE OF COCONUT WATER

Okolie *et al*. (2011) studied the fungal spoilage of husked and dehusked coconut fruits stored at 10°C and 30°C for three months. The husked coconut fruits stored at both 10°C and 30°C and the dehusked coconut fruits stored at 10°C showed no evidence of microbial spoilage at the end of the three months storage period. However, dehusked coconut fruits stored at 30°C deteriorated. *Aspergillus flavus* and *Aspergillus niger* were the principal fungal agents associated with the spoilage. An investigation of the proximate composition of the dehusked fruits stored at 30°C indicated a marked significant difference in the percentage composition of moisture, protein, ascorbic acid, and carbohydrate content of 3.97±0.28, 3.98±0.07, 0.01±0.002 and 9.27±1.02 respectively as against 46.82±0.43, 3.77±0.05, 2.48±0.15 and 11.89±0.22 obtained for dehusked coconut fruits prior to storage. These results suggest that the deterioration in nutritional composition was due to breakdown of protein and carbohydrate by the spoilage fungi. Further tests confirmed the ability of the isolated spoilage fungi to utilize the different carbohydrate and nitrogen sources as source of carbon and energy.

Fernanda *et al.* (2009) conducted a study to assess the quality of reconstituted fruit juices and coconut water sold for immediate consumption in bars, restaurants, and bakeries, and by street vendors in Belo Horizonte, Minas Gerais, Brazil. Microbial quality was determined by counting coliforms, yeasts, staphylococci, and salmonellae. Total titratable acidity, pH and total soluble solids of these beverages were recorded. For coconut water samples, the total reducing sugar content was also determined. The "juices" collected included reconstituted orange, cashew and grape-flavoured juice powders and concentrated cashew juice. sixty samples of these juices and 45 samples of coconut water were collected. More than half (55%) of the juice samples did not comply with current Brazilian legislation, which states that there must be a total absence of coliforms in a 50mL sample. sixteen percent of the coconut water samples exceeded the bacterial count limits defined in Brazilian law, with thermotolerant coliform densities above 102MPN/mL. The high levels of sugar and low pH found in the coconut water were

possibly related to the high yeast counts in most samples. Forty seven percent of coconut water samples showed staphylococcal counts above 103CFU/mL. The numbers of thermotolerant coliforms, yeasts and staphylococci found suggest unsatisfactory hygienic practices during the preparation of these beverages. Salmonellae were not detected in any of the samples.

2.3 EFFECT OF NON-THERMAL PROCESSING ON PRESERVATION OF TENDER COCONUT WATER

Das *et al.* (2012) investigated on micro filtered tender coconut water and found that with added l-ascorbic acid, microfiltered coconut water has been proven to be a better alternative to thermal methods. The concentrations of PPO and POD enzymes are reduced with an increasing concentration of ascorbic acid. Oxygen scavenging and the blockage of the active site of the enzyme catalyst could be attributed to the inactivation of enzyme activities. However, a higher amount of the additive causes an increased acidic flavour in TCW, which consequently reduced the overall acceptability of the product. Moreover, comparable results were obtained by, where the degradation of microfiltered TCW was prevented by additives such as ascorbic and citric acid as well as l-cysteine. Additionally, on the packaging aspect, TCW in glass bottles had the most superior quality in all aspects compared to plastic bottles (Mahnot *et al*., 2014).

Reddy, Das, and Das (2007) investigated on two-stage filtrations with low ash filter paper (Whatman 42) and cellulose nitrate membrane of 0.2µm opening successfully demonstrated the efficacy of membrane filtration in preserving TCW quality.

Mahnot, Gupta, and Mahanta (2019) studied the enzyme activity, microbial activity, and shelf life with additives. Comparable outcomes were documented, when TCW had undergone treatment of certain additives along with the process of, where it extended storage life up to 90 days without any undesirable effects. The declining enzyme activity could be attributed to the action of additives, ascorbic, and citric acid, as well as the retention of catalysts by the membrane. Furthermore, the process included 0.8 and 0.45µm pore size and subsequent addition of ascorbic

acid (180mg/L), citric acid (200mg/L), and orange honey (5%w/v) even though the latter had barely sufficient ability to destruct the enzymes. Membrane filtration is an emerging technique in the food processing sector. Nevertheless, the scientific literature about TCW processing based on different microfiltration methodology is comparatively less. The underlying principle for microfiltration is the size difference or sieving effect created by the filtration element. During microfiltration, a suitable pore size for the filtering element should be selected so that the enzyme gets retained on the element and all other components are allowed to pass through. This technique is a cold sterilization process sometimes coupled with other thermal and non-thermal processing methods for desired results.

Karmakar and De (2017) explored the feasibility of cold sterilization of TCW using hollow fibre ultrafiltration and found that Polyacrylonitrile (PAN) of 44KDa treated with sodium hydroxide act as the filtering membrane with the optimal operating condition of 138kPa transmembrane (TMP) pressure and 15L/h crossflow rate. The resistance in series model satisfactorily demonstrated the flux characteristics with a correlation coefficient of 0.99 and 0.98, respectively, for fouling and hydraulic resistance.

Sumonsiri (2019) conducted following treatment and developed a model, the model put forward 153–158kPa as TMP limiting range for Reynolds number 51–152. The transmembrane pressures and Reynolds number strictly affected flux profile, albeit; TMP had a more pronounced effect. Furthermore, shelf-life studies for 18 weeks performed in the sample had only minute changes from fresh coconut water as well, as it had the same organoleptic attributes. similarly, microfiltered coconut water also seems beneficial in TCW processing. Microfiltration process (Whatman polyethersulfone puradiscsyringe filter having a pore size of 0.2μm and 25mm diameter) with nisin (25–75ppm).

2.4. MEMBRANE PROCESSING OF TENDER COCONUT WATER AND FRUIT JUICES

Junmee and Tongchitpakdee (2015) conducted studies to determine the effects of membrane processing on quality of coconut water. Polysulfone membrane

with 0.2μm pore size was used in microfiltration (MF). After clarification using MF, coconut water was heated using Ultra High Temperature (UHT) process at 140°C for 4s. Hunter lab Color (L, a, b), total color difference (ΔE), browning index (BI), 5-hydroxymethylfurfural (HMF), haze, pH, and total soluble solids (TSS) of clarified coconut water were evaluated during storage at room temperature, 27°C for 28 days. Average permeate flux for MF was 20L/m2h. Haze formation in coconut water increased with storage time. Initial haze could be significantly removed by MF. Coconut water clarified using MF had lower total color difference (ΔE) when compared to initial sample (Day 0). At 28 days of storage, BI and HMF of coconut water clarified using MF were also lowest when compared to control. BI and HMF were positively correlated (r = 0.935). Clarification using MF with 0.2μm pore 13size could help extending shelf life of coconut water. MF treatment did not affect the pH and TSS of coconut water. Clarification using MF with 0.2μm pore size could extend the shelf life of coconut water by lowering haze, ΔE, BI and HMF. Therefore, MF could be an alternative treatment in coconut water processing to obtain high quality of coconut water with extended shelf life.

Nikhil *et al.* (2014) studied non-thermal two-stage microfiltration technique in aseptic conditions to preserve tender coconut water. Concentrations of citric acid (0.02g/100mL), ascorbic acid (0.18g/100mL) and L-cysteine (0.009g/100mL) were standardized according to taste and added to coconut water as natural additives. The coconut water was packed in glass and plastic bottles after flushing the headspace with nitrogen and stored under refrigeration (4°C). The microfiltered water was studied for microbial, sensory, and physicochemical properties for a period of 46 days. The quality of the water packed in glass bottles was better in all respects. The total soluble solids changed from 5.4 to 6°Brix. The pH changed from 5.7 to 5.8. The soluble sugar concentration increased from 1.9g/100mL to 3.1g/100mL, free fatty acid content increased from 0.064mg KOH/g to 2.8mg KOH/g at the end of 46 days, which was much lower than the changes in control. The protein content decreased in all the samples. Two-way ANOVA showed that the storage time had more impact on the sensory properties of the product than the packaging material. The glass bottled product was acceptable on sensory basis till 46 days of storage.

Chhaya *et al.* (2012) used cross flow ultrafiltration to clarify the pre-treated stevia extract. Two practical modes of cross flow ultrafiltration namely steady state under total recycle mode and batch concentration mode were used. It was observed that the significant flux enhancement was achieved with transmembrane pressure drop and cross flow rate. Maximum 200% flux enhancement with cross flow rate and 140% with transmembrane pressure drop were attained in the range of operating conditions studied herein. Effects of cross flow rate on the permeate properties were marginal but that of the transmembrane pressure drop was significant. Recovery of stevioside in the permeate was in the range of 30% to 56% for various transmembrane pressure drop and it was maximum for lower operating pressure, 276 kPa. However, the recovery of stevioside decreased to 38% at 276 kPa pressure after 10 h of operation. Nanofiltration was employed to concentrate the ultrafiltered liquor. During nanofiltration, the ultrafiltered feed was concentrated maximum twice at 1241 kPa and 1500 rpm of stirrer speed within 1 h of operation. Maximum overall purity and recovery of 60% is obtained when ultrafiltration followed by nanofiltration was used for a particular set of operating conditions.

Behnaz *et al.* (2011) studied the clarification of tomato juice through microfiltration process. Influence of transmembrane pressure (1, 2 and 3bar), crossflow velocity which corresponds with Reynolds number (300, 1500 and 2500) and temperature (30, 40 and 50°C) on permeate flux and some properties of clarified juice such as colour, turbidity, density, viscosity, pH, and total soluble solid have been studied. The results 15 revealed that the investigated parameters (i.e., Pressure, Temperature and Reynolds number) had an increasing effect on the permeate flux and colour and the greatest effect on the permeate flux and colour was supplied by crossflow velocity. The other permeate properties did not significantly change with variations of the operating parameters. The statistical analysis indicated that the interactional effect of crossflow velocity and TMP on the permeate flux was significant.

Carvalho *et al.* (2010) studied the preservation of pineapple juice which was first hydrolysed with a commercial pectinase (Ultrazym 100 G) and then clarified by microfiltration. A tubular polyethersulfone membrane with an average pore size

of 0.3μm and a total effective filtration area of 0.05$m2$ was applied. The transmembrane pressures were 1.5 and 3.0bar respectively and the processes was conducted at room temperature. The results showed that the pineapple juice permeate fluxes were of 57.77L/$m2$h at 1.5bar and 46.85L/$m2$h at 3.0bar. Concentration polarization and possibly fouling occurred during the processes. The best clarified juice fluxes were obtained when low transmembrane pressures, 1.5bar were applied. Jayanthi et al. (2010) reported clarification of tender coconut water in a continuous stirred ultrafiltration cell at transmembrane pressures of 276, 414, 552 and 690kPa and at stirrer speeds of 800 and 1600rpm, for each pressure. Permeate flux decline was analysed using a first-order kinetic model for the development of the polarized layer resistance. Correlations were proposed for the steady- state polarized layer resistance with the operating conditions, e.g., transmembrane pressure difference and membrane resistance. Decrease in membrane permeability after subsequent experiments was also quantified. Average irreversible fouling resistance was estimated as 7.5×1012 m-1. Using the developed design equations of the stirred continuous ultrafiltration system, finally, the performance of such system in terms of productivity as function of operating conditions, membrane area and number of cleaning cycles was also evaluated.

Narayanasami *et al.* (2010) studied reverse osmosis as a preservation method to concentrate the tender coconut water and to improve the shelf life with minimum change to its nutritional and other sensory attributes. Trials were made for dummy solution and coconut water to optimize the processing conditions based on their chemical compositions and sensory attributes. The total soluble solid content of concentrated juice was increased from 4.5% to 14.0%. Apart from this, other nutrients also increased 2-2.5 times of its original content. storage studies were carried out for membrane concentrated tender 16 coconut water, 25% and 50% upgraded tender coconut water concentrate (i.e., sucrose 45%, glucose 50%, maltose 4.5% and potassium chloride 0.5% were mixed to increase the concentration) as control, tender coconut water packed in sterile container and with chemical preservative (500ppm of sodium benzoate). The samples were stored at 30±2°C and at 12°C. No changes were observed in the samples kept at 12°C up to

43 days. At the same time, increase in the acidity, decrease in reducing sugar content and pH were noticed in the samples stored at 30±2°C within 22 days. Out of all these samples, 14% membrane concentrated tender coconut water and 25% upgraded tender coconut water without preservative in the sterile container at 12°C with minimum changes in chemical composition was accepted by panellists. The concentration of TCW was increased to its three-fold level with less overall acceptability. In this study 25% upgraded TCW sample without preservative at 12ºC was the best natural ready-to- serve TCW for more than 48 days.

Pelin *et al.* (2010) evaluated the potential of integrated membrane processes for the clarification and the concentration of apple juice. The fresh apple juice, with a total soluble solids (TSS) content of about 12°Brix was previously clarified by combined application of fining agents, gelatin, and bentonite and UF through 10 KDa or 100KDa molecular weight cut-off (MWCO) membranes on laboratory scale. The clarified juice was then concentrated by osmotic distillation (OD), membrane distillation (MD), coupled operation of OD and MD or by conventional thermal evaporation up to 65°Brix. The effect of different clarification and concentration processes on formation of 5- hydroxymethylfurfural (HMF), retention of bioactive compounds (phenolic compounds, organic acids, glucose, fructose, and sucrose) and their efficiency in preserving natural color and aroma (trans-2-hexenal, the most relevant compound in apple juice aroma) were evaluated in order to maintain a high-quality product. The new membrane-based concentration techniques were very efficient since the product characteristics were very similar to that of the initial apple juice especially regarding the retention of bright natural color and pleasant aroma, which are significantly lost during thermal evaporation. Furthermore, among all the concentration treatments applied, only thermally evaporated samples resulted formation of HMF. Phenolic compounds, organic acids and sugars were very stable against all concentration processes, including thermal evaporation. Coupled operation of OD and MD reduced trans-2-hexenal losses drastically tending towards that of the initial juice and hence can be proposed as the most promising alternative to conventional thermal evaporation technique.

Cassano *et al.* (2003) studied the clarification and the concentration of citrus (orange and lemon) and carrot juices. The reverse osmosis (RO) process, performed on a laboratory plant unit, was used to preconcentrate the permeate coming from the UF up to 15–20 g TSS/100 g. A final osmotic distillation (OD) step yielded a concentration of the retentate coming from the RO up to 60–63 g TSS/100 g at an average throughput of about 1kg h m-2. This laboratory unit was mainly used to develop operational parameters for the design of a full- scale plant and, secondly for the production of sample concentrates for their testing and evaluation. On the blood orange juice samples, it was demonstrated that the total antioxidant activity (TAA) of juices concentrated by evaporation was lower than that of the fresh juice. During the UF process TAA was maintained, with respect to the fresh juice, both for the permeate and for the retentate. A little decrease of the TAA was observed in the RO treatment, probably on account of the high pressure employed during the process. After this step, the subsequent concentration treatment by OD did not induce any significant changes to TAA independently from the final concentration obtained. Moreover, the juices concentrated by membrane technology retained their colour and large part of their aroma which is on the contrary lost during thermal concentration. Bottino et al. (2002) studied the production of new tomato juices based on the introduction of a MF stage before the RO stage. Ceramic multichannel membranes with an average pore size in the micrometre tenths were used in the MFstage to obtain a clarified serum to be concentrated by RO and a concentrated pulp to be used for remixing with the RO concentrate, in order to formulate new tomato juices. High temperature and pressure resistant spiral-wound RO membranes were used to concentrate the clarified serum up to 14–15°Brix with permeate fluxes around 20L/m2h.

Capannelli *et al.* (1992) studied the UF of Mediterranean orange and lemon juices using different types and configurations of membranes. The UF membranes used were polysulphone (20KDa to 200 KDa) and polyvinylidene fluoride (15KDa to 200 KDa). The MF ceramic membranes used had pore sizes of 0.5 to 0.8 μm. Applied pressures were in the range of 50 to 400kPa, feed temperatures were 20 to 40°C and feed velocities at membrane surfaces varied from 0.5 to 12m/s. It was

observed that the pulp, pectin, and essential oils were completely retained by the membranes. The permeate fluxes for orange juice were 30, 40 and 60L/m2h for polysulphone, polyvinylidene fluoride and ceramic membranes respectively. The permeate fluxes for lemon juice were 25, 35 and 50L/m2h for polysulphone, polyvinylidene fluoride and ceramic membranes, respectively.

Lira *et al.* (2012) evaluated the physicochemical and microbiological characteristics of coconut water filtered through ceramic MF membranes. The physicochemical characteristics of coconut water remained unaltered after microfiltration. The microbiological analyses indicated that raw and conventionally processed coconut water was unsuitable for human consumption. However, after microfiltration, the product was characterized as commercially sterile and suitable for consumption. Fecal and total coliforms were found to be below 0.3MPN/mL, mesophilic aerobic microorganisms showed values below 1.0CFU/mL, and salmonella was absent. These results confirm that treating coconut water by microfiltration through ceramic membranes is a viable procedure to remove microbiological flora without altering the product's original characteristics. It was concluded that the use of ceramic microfiltration membranes of 0.8μm pore size removes microbiological flora, rendering it fit for human consumption, without changing its nutritional and functional properties of coconut water.

2.5. MICROFILTERATION AND ITS PRINCIPLE

Microfiltration usually serves as a pre-treatment for other separation processes such as ultrafiltration, and a post-treatment for granular media filtration. The typical particle size used for microfiltration ranges from about 0.1 to 10μm. In terms of approximate molecular weight these membranes can separate macromolecules of molecular weights generally less than 100,000g/mol. The overall membrane flux of a microfiltration membrane can be given by using the following relation:

$$\mathbf{F = \alpha . \Delta P}$$

where, F represents the overall membrane flux, α the permeability constant, and ΔP the transmembrane pressure. (Singh and Purkait, 2019).

2.5.1. Modes and Modules

2.5.1.1. Modes

The two important modes of membrane process operations are dead end filtration and crossflow. Both are equally important and are used worldwide. Generally, the dead-end filtration is used in batch configuration and cross flow in continuous mode. Also, dead-end filtration is commonly used on a laboratory scale and crossflow is favoured to be used on industrial scale. These selections are based on the advantages and disadvantages of these modes of membrane operations, such as low fouling, scale of operation, etc. For example, the dead-end filtration provides high recovery as well as fouling. Therefore, the high recovery favour it for better recovery results and the fouling problem associated with it causes flux decline which make it unfavourable for large scale operations. Whereas cross flow provides less recovery and low fouling. This makes it a better choice for large- scale operations. Also, both the modes can be used in single or multiple pass configurations, which allow the feed or permeate to be circulated across the membrane single or multiple times to improve the efficiency of the overall membrane process. (Singh, and Purkait, 2019).

2.5.1.1.1. Batch

Batch mode is the most widely used mode of membrane processes. In this mode, a predefined amount of feed is provided to the membrane. The process runs until the feed is not over or refilled. It is advised as a virtuous mode of membrane process because it allows the cleaning of the membranes as well as the overall membrane setup in between two runs. This makes this mode of operation beneficial for the membrane process in terms of enhanced membrane process efficiency, membrane life, reduced cost, and low fouling. Therefore, it is best to be used in industries, such as food, pharmaceutical, and biotechnology.

2.5.1.1.2. Semi-Batch

Semi-batch mode of membrane processes is similar to batch mode of membrane operation with the only difference that it allows recirculation/addition/removal of feed/retentate/permeate. This arrangement helps in the improvement of selectivity and better control of the overall membrane process. Also, it helps in the reduction of total load on the downstream processing of permeate and retentate. This mode of membrane operations is widely used in process industries due to its low fouling and effective efficiency characteristics.

2.5.1.1.3. Continuous

Continuous mode of membrane processes consists of continuous addition of feed and removal of permeate from a membrane system. The main attribute of this system is that it is capable of handling large volumes of feed. This makes it an industry favourite because it reduces the overall membrane operation time. The only drawback of this system is fouling, which occurs due to the nature of its continuous operation and results in gradual decline in overall efficiency of the process. It would be suitable and has potential for the acceptance of membrane separation processes on a larger scale if membranes with better antifouling properties could be developed in the near future.

2.5.1.2. Modules

The industrial applications require a process to have capabilities to work efficiently and effectively on a large scale. In case of membrane processes too it is required for the membranes to handle large sums of feed to be acceptable on an industrial scale. Also, it is better for the membrane setups to be compact so that they acquire less space. Therefore, membranes are assembled in units which are

compact and also fulfil the area requirements of membranes to carry out the membrane process operations successfully. These units are known as modules, which are further characterized based on their geometry and configurations. (Singh, R., and Purkait, M.K, 2019).

2.5.1.2.1. Plate and Frame

Plate and frame membrane modules accommodate membranes of flat sheet configurations in a casket form. A plate and frame module are shown in figure. This arrangement makes it possible for the module to house more than one membrane in a stacked fashion that is one over other. The membranes are arranged in a fashion that the feed and permeate sides face each other and the module seems to be a compartment build-up offset of membranes.

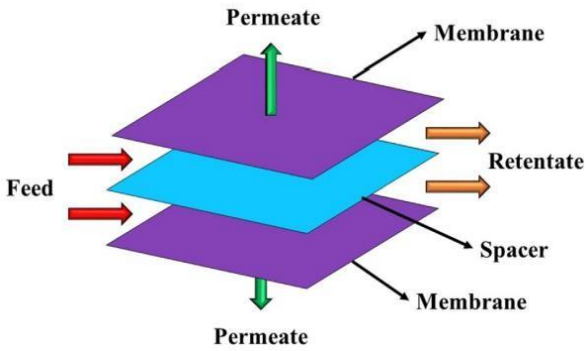


Fig 2.1 Plate and frame membrane

These individual compartments formed are separated by using spacers and the module is sealed. Furthermore, the module is housed between plates to form the final plate and frame module assembly. Plate and frame modules have packing density in the range of 100–400m^2/m^3.

2.5.1.2.2. spiral Wound

Spiral wound membrane modules are similar to plate and frame modules as they also accommodate flat sheet membranes but at the same time different as in

this module the membranes are wrapped around a permeant collection tube as shown in figure. This arrangement enhances the efficiency and effectiveness of the membrane module. Thus, spiral wound membrane module is among the most extensively used membrane modules. In this membrane module, the feed runs parallel to the central porous tube and this central porous tube also functions as the permeant collector. The average packing density provided by this membrane module is around 300–1000m^2/m^3. Generally, more than one membrane modules are used together so as to make the overall membrane process economical and efficient.

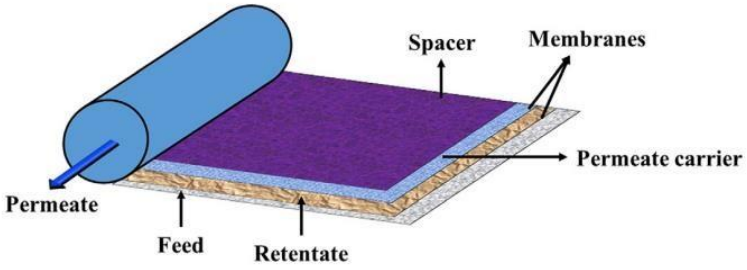


Fig 2.2spiral wound membrane.

2.5.1.2.3. Tubular

Tubular membrane modules are used for housing tubular membranes as shown in figure. In this membrane module, the tubular membranes are assembled inside a metallic, ceramic, or polymeric porous tube. This porous tube works as support for the tubular membranes. The number of tubular membranes that can be packed inside the supporting tube is not limited and can beset as per the requirement. This membrane module gets the feed through the tubular membranes and permeant is collected through the supporting porous tube. Tubular membrane module is commonly used for ceramic membranes with an average packing density of 300m^2/m^3.

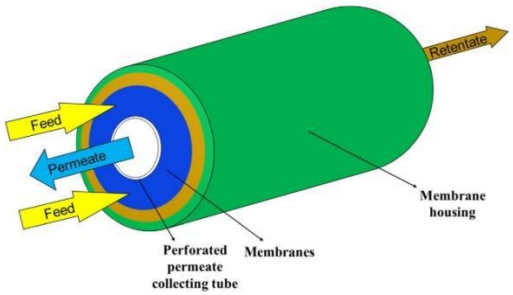


Fig 2.3 Tubular membrane module

2.5.1.2.4. Perforated Block

The tubular membrane modules are widely used for their better efficiencies and effective membrane operations. Therefore, they are further modified for enhanced overall membrane flux and selectivity. Perforated block membrane module is a good example of such a modified tubular membrane module. In this membrane module, a coarsely porous ceramic monolithic block is assembled into a supporting tube. This perforated block contains a number of cylindrical channels parallel to its length. The inner surface of these channels is used to have a layer of ceramic membrane. The permeant has to pass this layer of the ceramic membrane and thin walls of the membrane module so as to exit from the module. This arrangement provides possibilities for having number of channels with different shape variations.

2.5.1.2.5. Rotating Disk

Rotating disk membrane module is widely used membrane module in food, pharmaceutical, and biotechnology applications. This system provides a large area with minimal membrane fouling and enhanced membrane flux. In this membrane module, multiple disks are mounted on a single shaft and this system rotates between fixed circular membranes. Also, multishift systems are successfully developed and are in use in different parts of the world. This system is capable of using circular membranes with an average area of $2m^2$.

2.6. EFFECT OF MICROFILTRATION ON MICROBIAL LOAD

George and Golfo (2020) work were to assess the effect of the microfiltration (ceramic membranes 1.4μm, 50 ◦C) of partially defatted ovine milk (fat 0.4%) and bovine milk (fat 0.3%) characteristics. Feed milks, permeates and retentates were analysed for microbial counts, gross composition, protein fractions, the indigenous enzymes cathepsin D and alkaline phosphatase and the behaviour during renneting. It was showed that the microbial quality of both ovine and bovine permeate was improved by reduction of the total mesophilic microflora about 4 Log and 2 Log, respectively. The protein contents and the total solids contents of both permeates were significantly ($p < 0.05$) reduced. A further analysis of protein fractions by Reversed Phase -High Performance Liquid Chromatography (RP-HPLC) revealed lower αs1- and β-casein and higher κ-casein contents in permeates. The activity of alkaline phosphatase followed the allocation of the fat content, while activity of cathepsin D in permeates was not influenced, although somatic cells counts were removed. Regarding cheesemaking properties, the firmness of ovine curd made from the feed milk did not differ significantly from that made from the permeate. The obtained results suggested that microfiltration could be used for pre-treating of ovine milk prior to cheesemaking.

Xuejun *et al.(*2021) research has demonstrated that dissolved organic carbon leaching from plastics can stimulate microbial activity in the ocean. However, similar situation has not been reported in freshwater, like rivers and lakes. The interaction between microplastic and microorganism may probably change water quality, causing operational issues during membrane water treatment, such as increased biofouling, pore blockage or formation of filter cake. In this study, the influence of microplastics (polyethylene, PE) on membrane biofouling and the microbial community during continuous-flow ultrafiltration was investigated. Results demonstrate that PE microplastics stimulate microbial activity in natural surface water and increase the production of extracellular polymeric substances (EPS). The images of scanning electron microscope-energy dispersive spectrometer

(SEM-EDS) mapping have confirmed the presence of biofilm covered on the surface of microplastic particles. Biofouling layer became more hydrophobic with a dense and compact surface due to the accumulation of EPS stimulated by microplastics. specific components of EPS, especially tryptophan-like soluble microbial by-products with molecular weight distribution from 4KDa to 30KDa, were increased with the addition of microplastic and more likely to be entrapped by membrane pores aggravating membrane fouling. The components of EPS stimulated with the presence of microplastic was the main factor that caused membrane fouling. The microbial diversity was also affected with the addition of microplastic. In conclusion, the mechanism of membrane biofouling causing by microplastics in surface water is clear.

2.7. EFFECT OF CROSS FLOW VELOCITY AND TRANSMEMBRANE PRESSURE ON MICROFILTRATION

Zhao *et al.* (2014) According to this research, Ultrafiltration (UF, 0.05μm) with a ceramic membrane was combined with high-pressure processing (HPP) at 500MPa/6 min and high-temperature short time (HTST) at 110°C/8.6s to process fresh apple juice. The aim of this study was to compare the effect of UF + HPP and UF + HTST on quality features of fresh apple juice and analyse the quality changes of the juice treated by UF + HPP and stored during 60 days at 4°C. Applying UF, total plate count (TPC) and yeasts and molds (YandM) significantly decreased by 0.29 and 0.28 log cycle, total phenols and ascorbic acid decreased by 33.50 and 26.52 %, and antioxidant capacity, using the DPPH and FRAP assay, significantly decreased by 26.40 and 25.37 %. Meanwhile, the juice clarity was 99.75 ± 0.07 % and seven aroma compounds were changed. TPC and YandM in juices treated by UF + HPP and UF + HTST were <1 log cycle. When compared to the juice treated by UF + HTST, the juice treated by UF + HPP showed lower browning degree and higher total phenols and clarity and retained seven main volatile aroma compounds. Fresh apple juice processed by UF + HPP was microbiologically safe (TPC <1.8 log cycles and YandM <1 log cycle) during 60 days of storage at 4°C. The first-

order model was a suitable model for all quality parameters of refrigerated fresh apple juice; however, rate constant k of first-order model was between −0.0157 and 0.0350, showing the quality features of the refrigerated juice was stable.

Darvishzadeh and V.Priezjev (2012) study addresses the issue of oil removal from water using hydrophilic porous membranes. The effective separation of oil-in-water dispersions involves high flux of water through the membrane and, at the same time, high rejection rate of the oil phase. The effects of transmembrane pressure and crossflow velocity on rejection of oil droplets and thin oil films by pores of different cross- section are investigated numerically by solving the Navier–Stokes equation. We found that in the absence of crossflow, the critical transmembrane pressure, which is required for the oil droplet entry into a circular pore of a given surface hydrophilicity, agrees well with analytical predictions based on the Young–Laplace equation. With increasing crossflow velocity, the shape of the oil droplet is strongly deformed near the pore entrance and the critical pressure of permeation increases. We determined numerically the phase diagram for the droplet rejection, permeation, and breakup depending on the transmembrane pressure and shear rate. Finally, an analytical expression for the critical pressure in terms of geometric parameters of the pore cross- section is validated via numerical simulations for a continuous oil film on elliptical and rectangular pores.

Wua *et al*.(2007) study attempted to examine the effect of applied pressure on membrane fouling that might influence the potential use of ultrafiltration (UF) membrane in treating as well as recovering the biore sources, namely protein and carbohydrate from complex feed like palm oil mill effluent (POME). POME was first subjected to physical pre-treatment processes, consisting of depth and surface filtration in order to remove the total suspended solids (TSS). The pre-treatment processes enabled the reduction of TSS, turbidity, total dissolved solid (TDS) and chemical oxygen demand (COD) up to 97.3%, 88.2%, 3.1% and 46.9%, respectively. Protein (45.3%) and carbohydrate (41.5%) that retained as in soluble matters together with suspended solids might be used as fertilizer or animal feed by-products. Then, polysulphone UF membrane of 20KDa was used in the UF membrane study. This study indicated that the applied pressure imposed a direct

effect on fouling, permeate flux, protein and carbohydrate recovery as well as wastewater treatment. In total, the permeate flux decreased with filtration time until it reached steady- state values. Beyond a certain applied pressure between 0.6 and 0.8MPa, the increase in permeate flux with pressure was negligible and insignificance. The highest applied pressure (0.8Mpa) encouraged the formation of fouling up to 85.8% but at the same time enabled the recovery of protein and carbohydrate up to 61.4% and 76.4%, respectively. The highest reduction of TSS, turbidity, TDS and COD also occurred at 0.8Mpa up to 97.7%, 88.5%, 6.5% and 57.0%. The study revealed that it is possible to have appropriate control of applied pressure in order to favour fouling that would, in turn, lead to better rejection of other solutes present in the feed.

Gaddis (2007), in his study Ultrafiltration in a channel is considered for fluids having power-law viscous models dependent on concentration approximately in exponential fashion. A simple concentration solution profile is made to apply using mass conservation in a Steady state element. The solution applies to pre-gel and gel conditions. The viscous model is shown to affect the results in profound ways. A few observations are made concerning the meaning of gel. The average flux for a membrane channel is predicted to depend on pressure systematically. The flux for a gel-dominated channel is predicted to respond to the shear stress by the fluid on the membrane and thusly on the crossflow velocity. Values of the exponent in(flux)/In(velocity) are 1/3 for laminar flows of all fluids. The exponent exhibits larger values for turbulent flows, being increased for shear-thinning materials. This is the first known publication predicting the form of pressure effect and the first to explain values of the flux-velocity exponent as large or larger than unity.

2.8. EFFECT MICROFILTRATION ON FRUIT JUICE OR LIQUID FOODS

Laorko *et al.* (2013) Microfiltration (MF) is classified as a non-thermal process for the fruit juice industry. It could provide a better preservation of the phytochemical property and flavour of the juice. This work aimed to study the stability of phytochemical properties including vitamin C, total phenolic content,

antioxidant capacity (2-Diphenly-1picrylhydrazyl: DPPH, free radical scavenging capacity and Oxygen Radical Absorbance Capacity: ORAC assays), microbial and chemical–physical (color, browning index, pH and total soluble solid) properties of MF-clarified pineapple juice during storage at various temperatures (i.e., 4, 27, and 37°C). The juices were clarified by microfiltration using hollow fibre module. The results showed that most of the phytochemical properties and soluble components were retained in the juice after microfiltration. No microbial growth was detected after 6 months of storage. The storage time and temperature did not affect total soluble solids and pH ($P > 0.05$). The color (L^*) of clarified juice stored at 4°C was lighter than the juices stored at higher temperature levels ($P < 0.05$). The phytochemical properties and total phenol content of the juice significantly decreased as storage time and temperature increased ($P < 0.05$). Vitamin C content was the attribute that affected storage time and temperature most as indicated by reaction rate constant and activated energy. storage of nonthermally pasteurized and clarified pineapple juice at 4°C was the most suitable since it allowed the best quality preservation.

De *et al*. (2012) compared the performance of two membranes – tubular ceramic and hollow fibre poly(imide) – under transmembrane pressure of 0.5 and 1bar, for the clarification of passion fruit pulp pre-treated by centrifugation and enzymatic treatment at the concentrations of 150 and 300ppm. Nutritional and sensorial qualities of the clarified juice obtained were evaluated. Thus, it was possible to observe that the most adequate condition for the clarification of passion fruit pulp was with enzymatic treatment at 150ppm and its posterior microfiltration at the ceramic tubular membrane of 0.3μm with transmembrane pressure of 0.5bar. The fouling mechanism was identified by estimation of model parameters according to a nonlinear regression by Bayesian inference. Analysis of the fouling mechanism results revealed that hollow fiber membrane is controlled by a cake filtration mechanism, and internal pore blocking fouling mechanism controls ceramic tubular membrane.

To obtain clarified passion fruit juice, crossflow microfiltration after enzymatic liquefaction was studied by Vaillant *et al*. (1999) using ceramic

membranes with 0.2µm pore size. The effect of a high-rate enzymatic treatment for the degradation of suspended solids was assessed, resulting in the selection of a commercial enzymatic preparation. Partial enzymatic liquefaction of cell-wall polysaccharides prior to microfiltration provided an unusual pattern of flux increase after a short decline when crossflow velocity was high (7 ms^{-1}). It was found that a synergistic effect between pectinase and cellulase activities enhanced permeate flux increase. With total recycling at 36°C, the combination of low transmembrane pressure (150kPa) and high enzyme concentration (1mL l−1) provided the highest flux (113 $l\,h^{-1}\,m^{-2}$). These conditions were then assessed with concentration in order to verify industrial feasibility and evaluate physicochemical characteristics of final products. A volumetric reduction ratio of 3 was maintained during 18 h without any decrease in permeate flux, which fluctuated around 40L h^{-1} m^{-2}. The quality of permeate was satisfying even its aromatic strength was weakened. Retentate had similar characteristics of raw juice and could be recycled in order to use its residual enzyme activity.

Freshly squeezed orange juice was ultrafiltered in a hollow fibre crossflow ultrafiltration system. The suspended solids (pulp) in the juice were completely separated with a membrane cut-off of 5 X 10^5 molecular weight. The membrane retained most of the pectin material, and the viscosity of the permeate (juice serum) was appreciably reduced. Concentration of permeate by evaporation was achieved up to 75ºBrix. No pectinesterase activity was detected in the permeate. some aroma compounds, particularly hydrocarbons, remained in the retentate. Oxygenated aroma components such as alcohols, esters, and aldehydes remained in the permeate (Hernande, *et al*., 1992).

Fresh depectinised kiwifruit juice has been clarified by ultrafiltration (UF) process on laboratory scale. In experimental tests performed according to the total recycle mode the effect of transmembrane pressure (TMP), axial flowrate and temperature on permeation flux has been studied. The results showed that flux increased with temperatures from 20 to 30 ºC and with axial feed flow rate from 300 to 700L/h. The flux pressure curves showed no increase in permeate fluxes for TMP values higher than 90KPa (TMPlim). Clarified kiwifruit juice has been

produced in experimental tests carried out according to the batch concentration mode working in optimal operating and fluid dynamic conditions. The quality of clarified juice has been analysed in terms of total antioxidant activity (TAA), content of ascorbic acid, suspended solids, turbidity, and viscosity. The UF process permitted a good level of clarification totally reducing the suspended solids and the turbidity of the fresh juice. In the permeate a 16% reduction of ascorbic acid was observed with respect to the fresh juice; however, the reduction of the TAA was lower than 8%. Cake layer and irreversible fouling resistances gave a minimum contribution to the total resistance (2.23% and 2.75%, respectively) while the contribution of the reversible fouling was more significant (29.4%). A good restore of the hydraulic permeability of the membrane (about 96% of the initial one) was observed after a cleaning treatment performed by using alkaline and acid detergents. Thus, the flux decline during UF could be ascribed to fouling layers formed by a combination of suspended particles and adsorbed macromolecular impurities (Cassano, *et al*., 2007).

2.9 CHANGES IN CHEMICAL COMPOSITION OF BEVERAGES DURING STORAGE

2.9.1 Total soluble solids

Pandey (2004) reported that the RTS beverage prepared from guava pulp remained stable for a period of 4 months with increasing TSS content and good organoleptic score.

Saravanan *et al.* (2004) conducted an experiment to develop papaya ready-to- serve (RTS) beverage and observed that the TSS was increased during storage period.

Srinivas *et al.* (2007) conducted an experiment at UAS, Bangalore and revealed that, the TSS of pomegranate squash was increased during storage period. This might be due to hydrolysis of polysaccharides like cellulose and pectin substance into simple substance.

Pal *et al.* (2007) carried out an experiment to develop nectar by blending watermelon juice and coconut water and observed that TSS was increased slightly during the period of storage.

Das (2009) prepared different beverages viz., RTS, nectar, squash, and syrup from the jamun fruit and stored up to 6 months for the evaluation of physical and chemical analysis. It was reported that, during the storage period of 6 month, the total soluble solids of RTS remained unchanged up to two months, but it was increased after 2 month of storage period from 10.08 to 10.41.

Yadav *et al.* (2009) carried out an experiment on ready-to- serve (RTS) beverage with pummelo alone and pummelo blended with orange at two concentrations of 25 and 50 per cent. The products were treated with potassium metabisulphite for preservation and stored at ambient and at low temperature (8-10ºC) in sterilized and sealed glass bottles for a period of 10 90 days. The results indicated that the total soluble solids (TSS) increased gradually during storage.

Gehlot *et al.* (2010) observed that total soluble solids (TSS) increased in jamun RTS drink and nectar during three months of storage.

Byanna and Gowda (2012) observed that the TSS was increased during the six months of storage period in sweet orange RTS beverage.

Yadav *et al.* (2013) carried out an experiment on Ready to serve beverage from banana pulp and observed that the TSS was increased with increase in the storage period on particular temperatures.

Patil *et al*. (2014) develop RTS by blending rose apple and jamun and observed that TSS was increased during the three months of storage period. Lather et al. (2015) reported that the TSS content of aonla juice increased significantly from 8.16 per cent to 9.32 per cent with the increasing period of storage.

2.9.2 Titrable Acidity

Das (2009) observed that different beverages prepared from Jamun juice viz. RTS, nectar, squash and syrup and stored up to five months. The titrable acidity of RTS and nectar did not change in the first month of storage, but slight increase was observed up to end of 6 month of storage i.e., from 0.33 per cent to 0.46 per cent.

Sharma *et al.* (2009) carried out an experiment to develop the guava-jamun ready-to serve (RTS) drink and reported that the titrable acidity increased during storage for three months.

Gehlot *et al.* (2010) observed that acidity of jamun beverages decreased significantly with the advancement in storage period.

Byanna and Gowda (2012) observed that the acidity was increased up to the six months of storage period in sweet orange RTS beverage.

Yadav *et al.* (2013) carried out an experiment to develop Ready-to- serve beverage from banana pulp and observed that the acidity was increased with increase in the storage period of 90 days.

Patil *et al.* (2014) carried out an experiment to develop RTS by blending rose apple and jamun and concluded that the acidity decreases in corresponding increase in pH during three months of storage period.

Lather *et al.* (2015) conducted research on preservation of aonla juice by preservatives and thermal processing. study revealed that there was a significant increase in acidity during storage period.

2.9.3 Ascorbic Acid

Das (2009) reported that ascorbic acid content of all four product of jamun (RTS, nectar, squash, syrup) decreased continuously during entire period of storage. The range of decrease in RTS were found from 12.21 to 10.20, for nectar from 15.50 to 14.00, for squash, 17.60 to 15.20 and for syrup from 20.0 to 19.0, respectively.

Sharma *et al.* (2009) conducted an experiment to develop the guava-jamun ready-to serve (RTS) drink and reported that the ascorbic acid decreases with the increase in storage period.

Yadav *et al.* (2009) developed ready-to- serve (RTS) beverage with pummelo alone and pummelo blended with orange at two concentrations of 25 and 50 per cent. The products were treated with potassium metabisulphite for preservation and stored at ambient and at low temperature (8-10ºC) in sterilized and sealed glass bottles for a period of 90 days. The results indicated that the ascorbic acid content was decreased over the storage duration.

Byanna and Gowda (2012) observed that the ascorbic acid was decreased during the six months of storage period in sweet orange RTS beverage.

Patil *et al.* (2014) carried out an experiment to develop RTS by blending rose apple and jamun and reported that the ascorbic acid was decreased during three months of storage period.

Chauhan *et al.* (2014) carried out an experiment to develop a refreshing beverage by blending coconut water and lemon juice and observed that the ascorbic acid was decreased during storage period at room temperature.

Lather *et al.* (2015) observed that there was significant decrease in ascorbic acid content of aonla juice with the increasing period of storage.

2.9.4 pH

Reddy and Chikkasubhanna (2008) reported that the pH of aonlasquash was found to be increased for three months storage. A corresponding decreased in acidity was recorded due to chemical reaction taking place between organic acid and pigment. It could be responsible for change in pH.

Mehmood *et al.* (2008) observed that the pH values decreased consistently with the advancement of storage time in apple juice.

Byanna and Gowda (2012) carried out an experiment to standardize the recipe of sweet orange RTS beverage at processing laboratory in the Division of Post Harvest Technology, Indian Institute of Horticultural Research, Bangaluru and observed that the pH was decreased during the six months of storage period.

Chauhan *et al.* (2014) carried out an experiment to develop a beverage by blending coconut water and lemon juice and observed that the pH was decreased during six month of storage period at room temperature.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter deals with different materials and methods adopted for the study of microfiltration of tender coconut water and the procedure followed for the evaluation of this technology. The procedures adopted for the evaluation of physiochemical, microbial, and sensory qualities of tender coconut water are also explained in detail.

3.1 RAW MATERIAL AND PRETREATMENTS

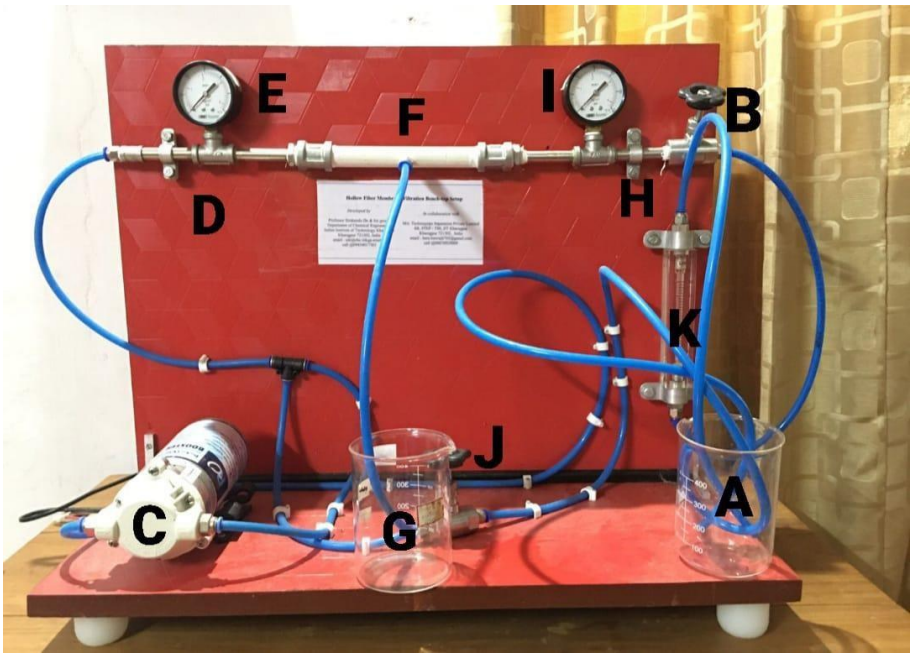
Tender coconuts required for the study were collected from the Instructional farm of Kelappaji College of Agricultural Engineering and Technology, Tavanur, Kerala. Prior to treatment, the coconut water was filtered using a sieve made from 304 grade stainless steel wire mesh. The tender coconut water collected was stored under refrigerated condition (4±2°C) until the beginning of membrane separation experiments.

3.2 OPERATION OF CROSSFLOW MEMBRANE CELL

3.2.1 Microfiltration Equipment/ Laboratory setup

The schematic of hollow fibre membrane setup is shown (Plate 3.1). The heart of the setup is the hollow fibre module (F). The feed is drawn by the booster pump (C) and fed to the module by 6mm polyurethane tube via a Perspex flange. Two pressure gauges in the range of 0 to 60psi are attached to the upstream and downstream of the module. A ¾ inch needle valve (B) of stainless steel has been fitted in the retentate line after the module. This valve is used for fine tuning of pressure and flow rate through the module. A rotameter (K) of range O to 50 lph is attached to the retentate line and the retentate stream is recycled back to the feed tank (A). A bypass line is connected from the pump to the feed tank and a 2"stainless steel needle valve (B) is attached to the bypass line. The permeate flows through a

5mm polyurethane pipe into permeate collector (G). By controlling the bypass valve (J) and retentate valve (U), one can control the flow rate and the transmembrane pressure drop across the module, independently. The transmembrane pressure drop is the arithmetic average of the readings in the pressure gauges E and I. The physical dimension of the setup is 70mm in length, 48mm in width and 65mm in height. The weight of the setup is approximately 10 kg. One power point of domestic line 220 V is required to run the pump.



A: Filtration tank E: Upstream pressure gauge(0-60psi) J: Bypass Valve
B: Needle valve F: Hollow fibre module K: Rotameter (0-50LPH)
C: Booster pump G: Permeate collector
D and H: short piece I: Downstream pressure gauge(0-60psi)

Plate 3.1 schematic of the membrane filtration setup

3.2.2 Cleaning Protocol after operation of the Plant

1. After an experiment, the membrane was washed following the protocols before disassembling. The membrane cartridges were always kept in distilled water with formaldehyde (4%). The cleaning protocol is followed again before using the plant.

2. The first wash is with tap water. Run the setup at minimum TMP(1-2psi) and high cross flow rates (30-40L/h) for 15 minutes. After the procedure repeat the step with distilled water for 2-3 minutes.
3. Measure the pure water flux at constant flow rate of 30L/h and evaluate the permeability. If the permeability falls below 0.7(70%) of that of the nascent membrane, go for acid alkali wash.
4. For acid wash run the membrane at low TMP (1-2psi) and high cross flow rates (3040L/h) with 0.1 N hydrochloric acid (HCl) for 30 minutes in total recycle mode. After that, run the setup at low TMP (1-2psi) and high cross flow rates (30-40L/h) in total recycle mode with 0.1 N sodium hydroxide (NaOH) for 30 minutes.
5. Then wash the setup with distilled water keeping only the suction line in the feed tank. Take appropriate quantity of sample and carry out the filtration process.

3.2.3 Operation of Membrane Plant for Conducting Experiments

The hollow fibre membrane unit is initially washed with distilled water for 30 minutes. 250mL of the tender coconut water before microfiltration was kept aside for initial physiochemical analysis. Pre-treated tender coconut water (250mL) is taken in a 500mL beaker and pumped into the hollow fibre module using a booster pump. It passes through the suction line to the hollow fibre unit. The transmembrane pressure (TMP) drop was maintained as 5psi. Permeate was collected in a beaker placed on a balance and the concentrate returned to the feed tank. Circulation of the tender coconut water continues until maximum permeate is obtained.

The procedure was repeated for 10, 15psi transmembrane pressure using microfiltration membrane separately and the different samples were evaluated.

3.3. EXPERIMENTAL DESIGN

3.3.1 Independent variables

- Transmembrane pressure (TMP)

  P1: 5psi

  P2: 10psi

  P3: 15psi

3.3.2 Dependent variables

The physicochemical properties *viz.* TSS, color, pH, titrable acidity and ascorbic acid of fresh sample and treated samples are analysed to optimize the process parameters of microfiltration.

1. Ascorbic acid
2. Titrable acidity
3. Total soluble solids
4. Color
5. pH
6. Mineral composition
7. Microbial count

3.4 QUALITY EVALUATION OF TENDER COCONUT WATER

Physiochemical properties such as pH., color, total soluble solids (TSS), titrable acidity, ascorbic acid content, turbidity and total sugar of the tender coconut water was analysed. The procedure followed for the analysis are detailed in following sections.

3.4.1 pH

pH of the tender coconut water was determined using a digital pH meter MK VI(SYSTRONICS). pH was originally defined as the decimal logarithm of the

reciprocal of the molar concentration of protons. Calibration is done before usage for more accurate and tuned readings.

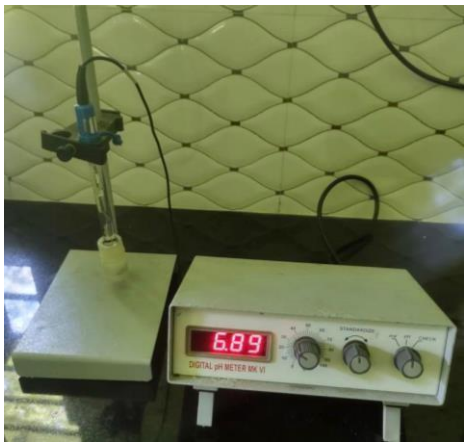


Plate 3.2 pH meter

3.4.2 Total soluble solid

The TSS of the samples was determined using a digital refractometer (Plate 3.2). When light passes from one medium to another, the speed at which the light travels will change depending on the parameters of the materials. The ratio or change in speed of light is called refractive index and instruments that measure this parameter is called refractometer. A refractometer can display the concentration in suitable units, such as Brix (% sugar). Calibration is done initially using distilled water. The reading should be zero for distilled water and after a drop of tender coconut water was placed on the measuring port of the refractometer to read the value of TSS. Readings were recorded.

Plate 3.3 Refractometer

3.4.3 Color

The color of the tender coconut water was found using a Hunter lab color flex meter (Hunter Association laboratory, Inc., Reston, Virginia, USA; model: Hunter Meter Lab's Color Flex EZ) as shown in plate 3.3.

The Hunter lab's color flex calorimeter consists of measurement (sample) port, opaque cover, and display unit. This color flex meter operates on the theory of focusing the light and measuring energy reflected from the sample across the entire visible spectrum. For matching a sequence of color across the visible spectrum primary lights are required and describes the color by mathematical model called as Hunter model. It reads the color of sample in respect of L*, a* and b* values where, luminance (L) forms the vertical axis, which denotes whiteness to darkness. Chromatic portion of the solids is designated by redness a (+), greenness a (-), yellowness b (+), and blueness b (-). A transparent glass cup filled with sample was placed over the port of the instrument and an opaque cover which act as a light trap to exclude the interference of external light was placed over the cup. Before actual measurements color was calibrated by fixing the definite colours like white and black tiles. After calibration, the sample was placed over the port and values of L*, a* and b* were recorded and repeated three times.

Plate 3.4 Colorimeter

3.4.4 Titrable acidity

Total acidity of samples was estimated and expressed as malic acid percentage (AOAC, 2000). Five millilitres of juice were taken in 250mL conical flask and 100mL of distilled water was added in the flask. Then few drops of phenolphthalein were added to the solution and mixed thoroughly. This solution was titrated against 0.1 N NaOH solution until the solution became the faintest discernible pink color which persisting for 30seconds. Acidity was calculated using the following formula:

$$Acidity\ (\%) = \frac{\text{ml of titrant} \times \text{Normality of titrant} \times \text{Eq wt}}{Sample\ weight\ (g)}\ x\ 100 \quad \ldots\ldots\ldots\ldots \text{(Eqn 01)}$$

Eq wt – Equivalent weight of the acid (mg/mEq) 0.067 milliequivalent of malic acid

3.4.5 Ascorbic acid

Ascorbic acid content in tender coconut water samples were estimated using the 2,6dichlorophenol indophenols titrimetric method as described by sadasivam and Manickam (1992). Dye solution was prepared by dissolving 52mg of 2,6 dichlorophenol indophenol, and 42mg of sodium bicarbonate in 200mL distilled water. standard solution was prepared by adding 100mg of ascorbic acid to 100mL

of 4% oxalic acid. To prepare working standard solution, 10mL of standard solution was pipetted out and was diluted to 100mL using 4% oxalic acid. The 5mL tender coconut water samples were made up to 50mL using 4 percent oxalic acid. To find dye factor, 10ml of working standard solution was pipetted out into a 50mL conical flask and 10mL of 4% oxalic acid was added and titrated against the dye. The end point was the appearance of pink color which persisted for a few minutes. The titration was repeated to get concordant values. The amount of dye consumed was equal to the amount of ascorbic acid present in the working standard solution (V1). Ten millilitre of the sample extract was pipetted out to which 10mL of 4% oxalic acid was added. It was then titrated against the dye. The titration was repeated for each sample until the concordant values were obtained (V2).

$$Dye\ Factor = \frac{0.5}{Titrable\ value(V1)} \text{.....(eqn 02)}$$

$$Ascorbic\ Acid\left(\frac{mg}{100g}\right) = \frac{0.5\ mg}{V1\ ml} \times \frac{V2}{5\ ml} \times \frac{100\ ml}{Wt.of\ the\ sample} \times 100 \text{ ..... (Eqn 03)}$$

Where, V1 - Amount of dye consumed by ascorbic acid present in the working standard solution.

V2 - Amount of dye consumed by the liquid sample.

3.4.6 Minerals

The sodium and potassium in the samples were determined using flame photometer and calcium and magnesium in the samples were determined using absorption spectrometer. Flame photometer is an instrument used in inorganic chemical analysis to determine the concentration of certain metal ions, among them sodium, potassium, lithium, and calcium. Group 1 and Group 2 metals are quite sensitive to Flame Photometry due to their low excitation energies. In principle, it is a controlled flame test with the intensity of the flame color quantified by photoelectric circuitry. The intensity of the colour will depend on the energy that

had been absorbed by the atoms that was sufficient to vaporise them. The sample is introduced to the flame at a constant rate. Filters select which colours the photometer detects and exclude the influence of other ions. Before use, the device requires calibration with a series of standard solutions of the ion to be tested.

Absorption spectrometry is a Spectro analytical procedure for the quantitative determination of chemical elements by free atoms in the gaseous state. Atomic absorption spectroscopy is based on absorption of light by free metallic ions.

In analytical chemistry the technique is used for determining the concentration of a particular element (the analyte) in a sample to be analysed. The technique makes use of the atomic absorption spectrum of a sample in order to assess the concentration of specific analytes within it. It requires standards with known analyte content to establish the relation between the measured absorbance and the analyte concentration and relies therefore on the Beer– Lambert law.

3.5 SHELF-LIFE ANALYSIS

Various physiochemical analysis is repeated at different storage periods. The quality is tested after 6-7 days interval to evaluate the shelf life and changes to the sample under refrigerated conditions (4±2 ℃).

3.6 MICROBIOLOGICAL ANALYSIS

The microbiological quality characteristics of the tender coconut water samples were determined both for fresh and optimized samples at different storage periods. The growth of bacteria was found through standard plate count method and serial dilution agar plate technique. Mould and yeast isolates were purified on potato dextrose agar, bacteria on nutrient agar, and further subculture for microscopic examination and identification.

3.6.1 Total bacterial count in tender coconut water samples

The bacterial population in tender coconut water samples were analysed by different microbiological methodologies, that includes enumeration of the

microorganism in selective media for different dilutions of sample, incubation of plates and counting the number of colonies present. The media generally used for enumeration bacteria is nutrient agar medium. The tender coconut water of 1 mL was pipetted using a sterile pipette into a test tube containing 9mL of sterile water which gave a l:10 (10) dilution. The test tubes were shaken well for 10-15 minutes for uniform distribution of microbial cell in the water blank. Then 10 dilution was prepared by pipetting out 1mL of (10) dilution to 9mL of sterile water in test tube with a sterile one mL pipette, The process was repeated up to 10^{-6} dilutions with a serial transfer of the dilutants. One millilitre of aliquots from 10^{-4} and 10^{-5} dilutions were transferred to the sterile petri dishes for the enumeration of bacteria.

Approximately, 15-20mL of molten and cooled (45°C) agar medium was added to each Petri dish containing the sample dilutions and the plates were rotated in clockwise and anticlockwise direction for thorough mixing of the dilutants and the medium. The plates were then incubated at 35°C (room temperature) for 24-48 hours for bacteria. After the incubation period, the colonies were counted and the number of organisms (total bacteria) per gram of sample was calculated by using the equation,

Number of colonies forming units (cfu) per gram of the sample

$$= \frac{mean\ number\ of\ cfu \times Dilution\ factor}{Quanity\ of\ sample\ on\ weight\ basis} \ldots\ldots\ldots \text{(Eqn 04)}$$

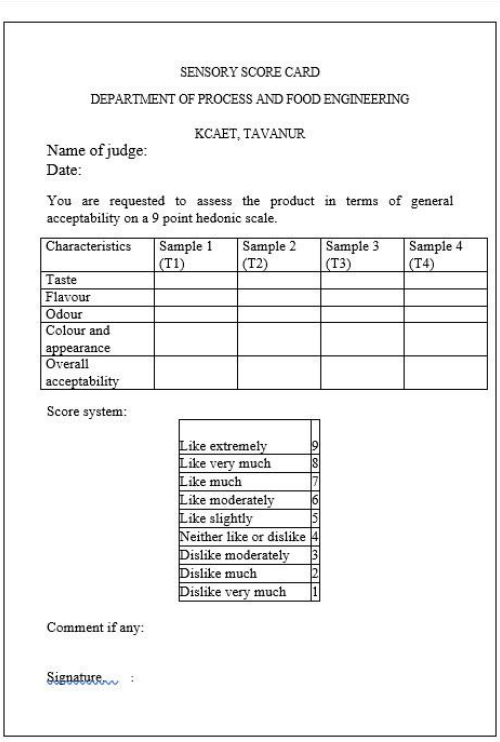
3.6.2 Plate count method for yeasts and moulds

Moulds were identified on the basis of morphological and cultural characteristics such as colour of the colony, surface, appearance, presence, and absence of cross walls, and asexual and sexual reproductive structures (Pitt and Hocking. 2009).

The cfu was measured by following the above procedure using potato dextrose or chloramphenicol as the nutrient media.

3.7 SENSORY ANALYSIS

sensory analysis is a scientific study used to measure, analyse, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch, and hearing. In general, sensory quality of liquid food is the consumer's reaction to the physical nature and chemical constituents of the food in its prepared and formulated form. Organoleptic evaluation was carried out by a panel of fifteen untrained judges for color, flavour, aroma, and overall acceptability using nine-point hedonic scale.



SENSORY SCORE CARD

DEPARTMENT OF PROCESS AND FOOD ENGINEERING

KCAET, TAVANUR

Name of judge:
Date:

You are requested to assess the product in terms of general acceptability on a 9 point hedonic scale.

Characteristics	Sample 1 (T1)	Sample 2 (T2)	Sample 3 (T3)	Sample 4 (T4)
Taste				
Flavour				
Odour				
Colour and appearance				
Overall acceptability				

Score system:

Like extremely	9
Like very much	8
Like much	7
Like moderately	6
Like slightly	5
Neither like or dislike	4
Dislike moderately	3
Dislike much	2
Dislike very much	1

Comment if any:

Signature :

Figure 3.1 sensory rating hedonic scale chart

RESULTS AND DISCUSSION

CHAPTER IV
RESULTS AND DISCUSSION

In this chapter the details of the results of the effect of microfiltration on TCW at different TMP to enhance shelf life have been presented. Physico-chemical and microbiological properties of stored TCW have been evaluated during the storage period and significant observations are discussed.

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4.1. VARIATION OF PERMEATE FLUX DURING MEMBRANE FILTRATION OF TENDER COCONUT WATER

Permeate flux variation of tender coconut water during microfiltration with pore size. 0.1µm membrane at 5, 10 and 15psi (Table 4.1) was recorded. Initially the flux was observed to be 22 LPH at 5psi and then increased gradually to 42 LPH as transmembrane pressure was increased up to 15psi. This is as per the Darcy's law which relates driving force with permeate flux. similar increase in permeate flux was observed by Jiang *et al.* (2018)

Table 4.1 Permeate flux of tender coconut water during microfiltration with different.

	TMPs	
S.No.	**Transmembrane Pressure, psi**	**Permeate flux, LPH**
1	5	22
2	10	29
3	15	42

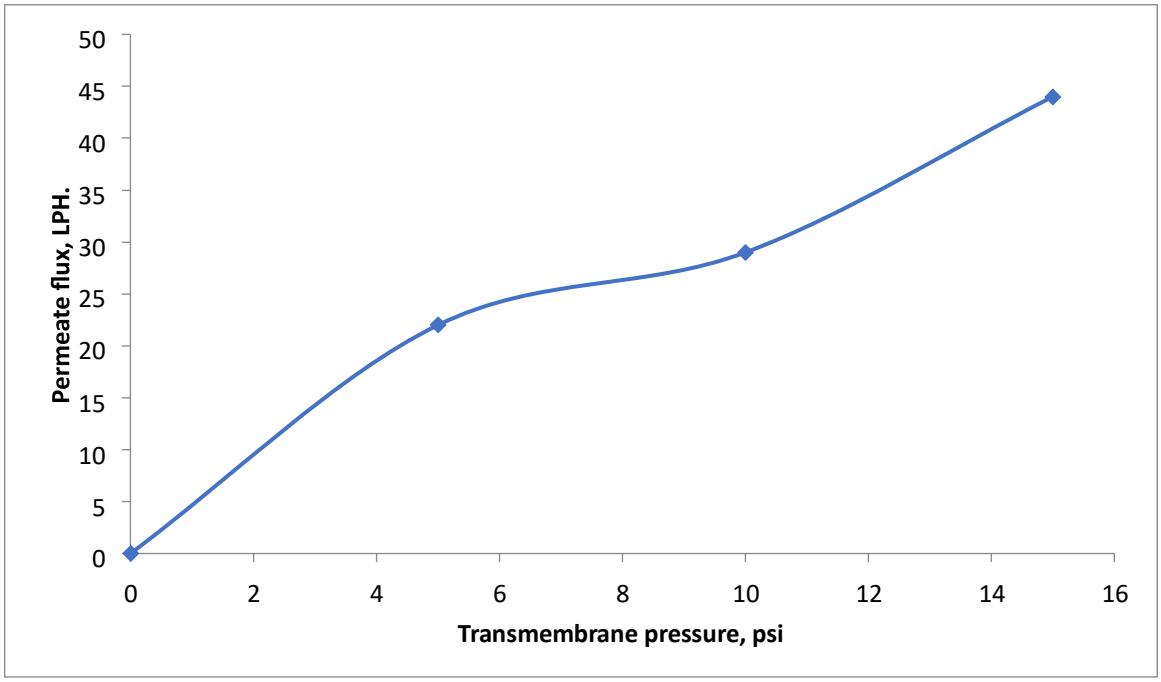

Fig. 4.1 Variation of permeate flux during microfiltration at different TMPs.

4.2. EFFECT OF DIFFERENT TREATMENTS ON PHYSICO CHEMICAL PROPERTIES OF STORED TENDER COCONUT WATER

4.2.1 Changes in Total soluble solids

Total soluble solids (TSS) of each treatment were found, the values gradually decreased with time in all treatments. The TSS of control T1, was very high initially and then decreased from 5.6 to 4.7°Brix. The TSS of treatment T2 was also initially 4.7°Brix and then after 28th days of storage it was observed to be 4.4°Brix. TSS of treatment T3 was initially 4.85°Brix and then after 28th days of storage it was observed to be 4.5°Brix. TSS of treatment T4 was initially 4.9°Brix and then after 28th days of storage it was observed to be 4.7°Brix. It is observed that TSS generally decreased on storage for all the treatments in the study as shown in Table 4.2 and Fig. 4.2.

The tender coconut water comprises of sugars, minerals, and other nutrients. The initial TSS of the treatments were found to be slightly low because some of the complex sugars and cloud forming solids may have been retained in filtration

because of their higher molecular size. TSS in all treatments decreased during storage probably due to fermentation process. similar observation was made by Rosa *et al*. (2012). The TSS of treatments particularly untreated TCW reduced probably more due to the conversion of carbohydrates into sugars, organic acids, and other soluble materials by metabolic processes during storage (Manashi *et al*., 2012).

Table 4.2 Changes in TSS of different treatments of tender coconut water during storage

Treatments	Total soluble solids, Brix				
	Day 1	Day 07	Day 14	Day 21	Day 28
Control (T1)	5.6	5.5	5.5	4.9	4.7
5psi (T2)	4.7	4.8	4.6	4.6	4.4
10psi (T3)	4.85	4.7	4.8	4.7	4.5
15psi (T4)	4.9	4.9	4.75	4.7	4.7

T1 –Control; T2 – Microfiltration (0.1 µm, 5psi); T3 – Microfiltration (0.1 µm, 10psi); T4 – Microfiltration (0.1 µm, 15psi)

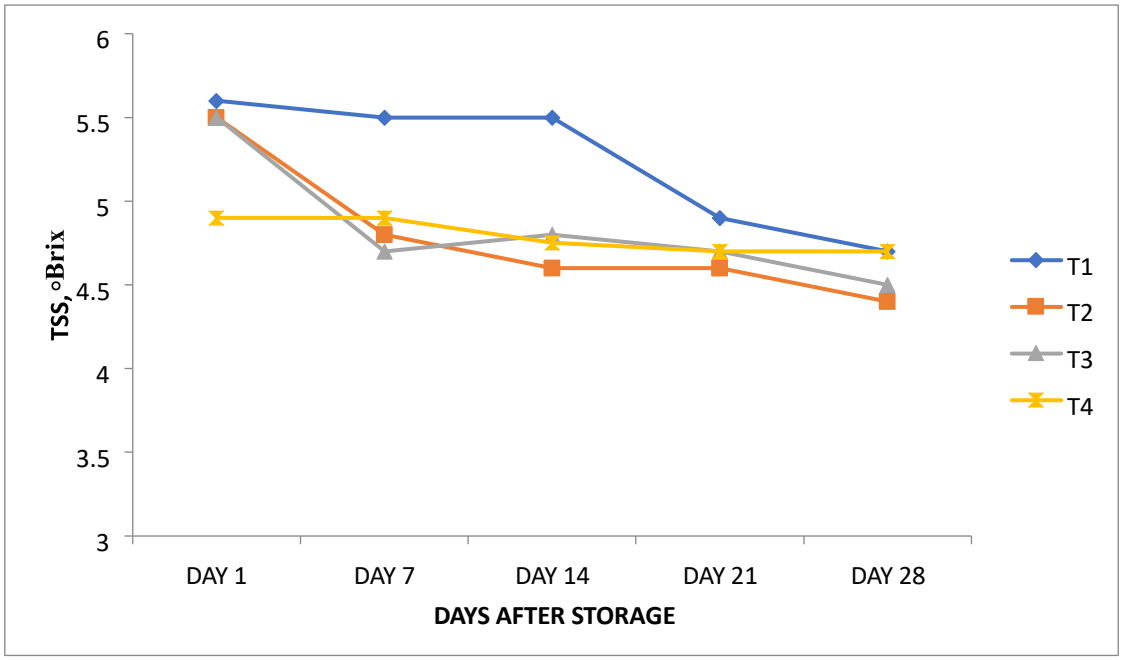

Fig. 4.2 Variation in TSS of different treatments of tender coconut water during Storage

4.2.2. Changes in pH

The pH of tender coconut water generally decreased upon storage in the study (Table 4.3 and Fig. 4.3). The pH of control T1 decreased from 5.08 to 4.62. The pH of treatment T2 was initially 5.28 and then after 28th days of storage it was observed to be 4.56. pH of treatment T3 was initially 5.16 and then after 28th days of storage it was observed to be 4.73.

TSS of treatment T4 was initially 5.20 and then after 28th days of storage it was observed to be 4.75. It is observed that pH generally decreased on storage for all the treatments in the study. (Table 4.3 and Fig. 4.3). The pH in general decreased upon storage which could be due to the production of free acids by microbial growth or by polysaccharides (Manashi *et al*., 2012).

Table 4.3 Changes in pH of different treatments of tender coconut water during storage

Treatments	pH				
	Day 1	Day 07	Day 14	Day 21	Day 28
Control (T1)	5.08	5.26	4.88	4.68	4.62
5psi (T2)	5.28	5.09	5.16	4.76	4.56
10psi (T3)	5.16	5.41	4.88	4.79	4.73
15psi (T4)	5.20	5.11	5.02	4.89	4.75

T1 –control; T2 – microfiltration (0.1 µm, 5psi); T3 – microfiltration (0.1 µm, 10psi); T4 – microfiltration (0.1 µm, 15psi)

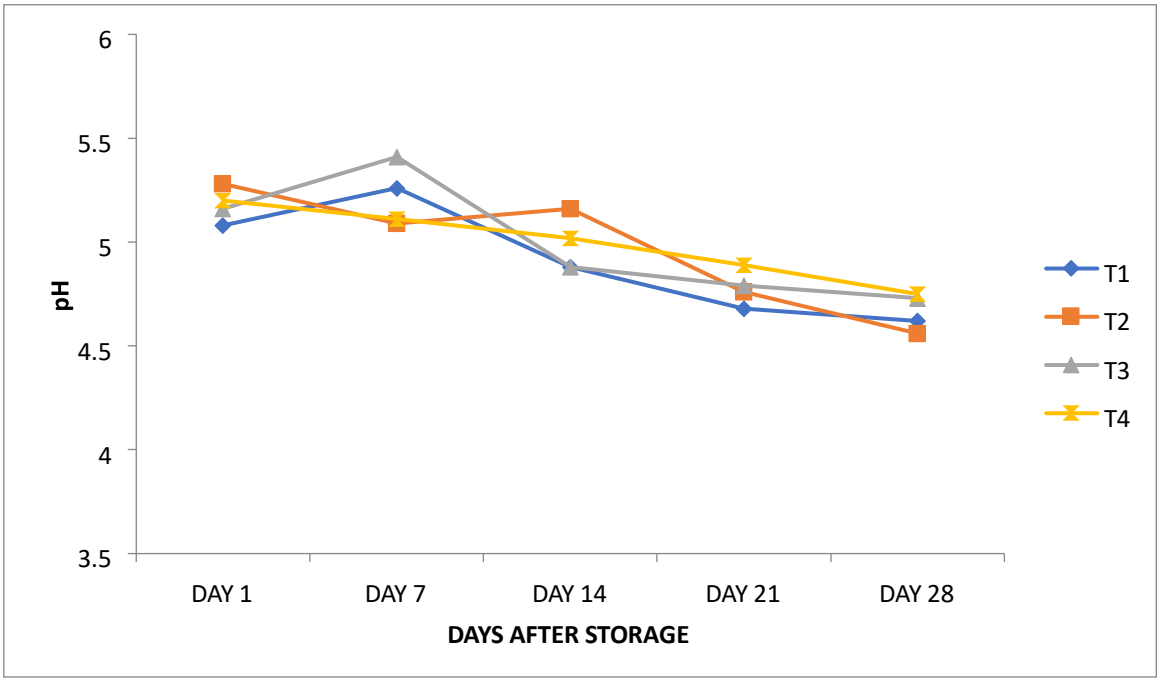

Fig. 4.3 Variation in pH of different treatments of tender coconut water during storage

4.2.3. Changes in Titrable acidity

Titrable acidity of each treatment were found, the values gradually increased with time in all treatments. The titrable acidity of control T1 increased from 0.137 to 0.224. The titrable acidity of treatment T2 was initially 0.137 and then after 28th days of storage it was observed to be 0.172. Titrable acidity of treatment T3 was initially 0.133 and then after 28th days of storage it was observed to be 0.169. Titrable acidity of treatment T4 was initially 0.134 and then after 28th days of storage it was observed to be 0.166. It is observed that Titrable acidity generally increased on storage for all the treatments in the study. (Table 4.4 and Fig. 4.4). The increase in titratable acidity was concomitant with the decrease of pH value, which could be due to the production of free acids by microbial growth. similar observations were made by Mahnot *et al.* (2014).

Table 4.4 Changes in Titrable Acidity of different treatments of tender coconut water during storage

Treatments	Titrable Acidity				
	Day 1	Day 07	Day 14	Day 21	Day 28
Control (T1)	0.137	0.153	0.179	0.202	0.224
5psi (T2)	0.137	0.140	0.146	0.160	0.172
10psi (T3)	0.133	0.138	0.145	0.152	0.169
15psi (T4)	0.134	0.137	0.146	0.155	0.166

T1 –control; T2 – microfiltration (0.1 µm, 5psi); T3 – microfiltration (0.1 µm, 10psi); T4 – microfiltration (0.1 µm, 15psi)

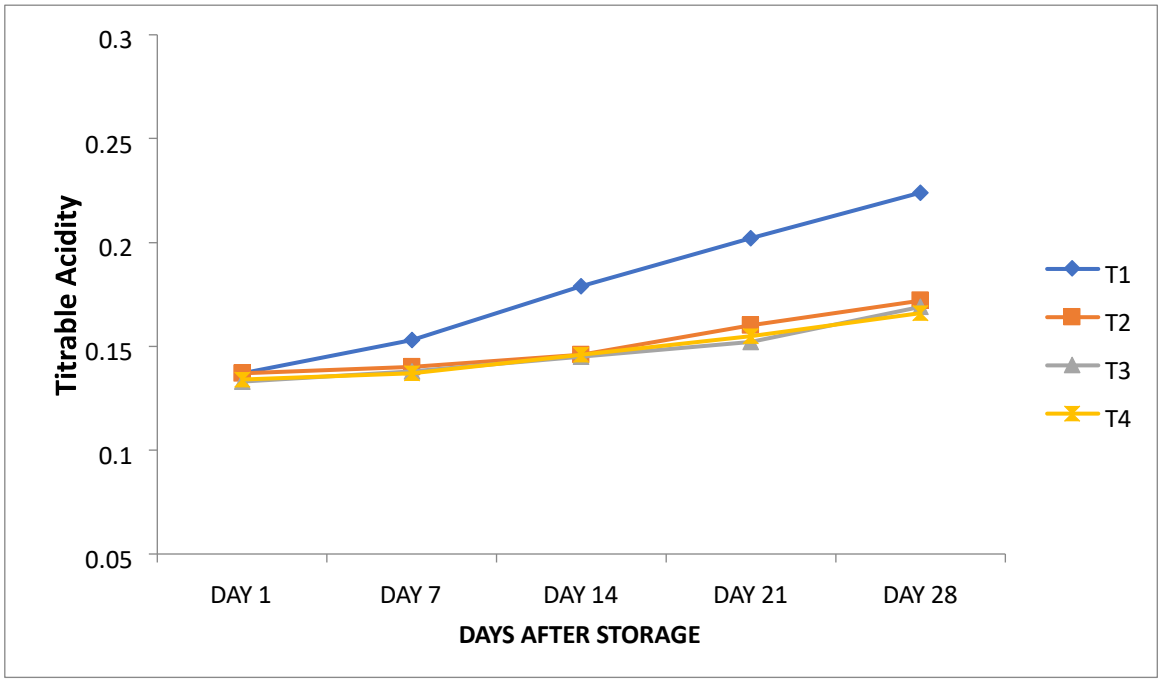

Fig. 4.4 Variation in titrable acidity of different treatments of tender coconut water during storage

4.2.4. Changes in ascorbic acid

Ascorbic acid of each treatment was found, the values gradually decreased with time in all treatments. The ascorbic acid of control T1 was very high initially

and then decreased from 6.78 to 0.62. The ascorbic acid of treatment T2 was initially 6.75 and then after 28th days of storage it was observed to be 3.76. Ascorbic acid of treatment T3 was initially 6.77 and then after 28th days of storage it was observed to be 3.81. Ascorbic acid of treatment T4 was initially 6.77 and then after 28^{th} days of storage it was observed to be 3.95. It is observed that ascorbic acid generally decreased on storage for all the treatments in the study. (Table 4.5 and Fig. 4.5). This can be attributed to the immediate reaction of an amount of ascorbic acid with the dissolved oxygen similar observations were made by Polydera *et al.* (2003). The lower rate of further ascorbic acid degradation is controlled by different mechanisms of anaerobic decomposition of ascorbic acid.

Table 4.5. Changes in Ascorbic acid of different treatments of tender coconut water during storage

Treatments	Ascorbic Acid				
	Day 1	Day 07	Day 14	Day 21	Day 28
Control (T1)	6.78	3.93	2.01	0.98	0.62
5psi (T2)	6.75	5.70	4.95	4.30	3.76
10psi (T3)	6.77	5.82	5.11	4.35	3.81
15psi (T4)	6.77	5.87	5.02	4.43	3.95

T1 –control; T2 – microfiltration (0.1 µm, 5psi); T3 – microfiltration (0.1 µm, 10psi); T4 – microfiltration (0.1 µm, 15psi

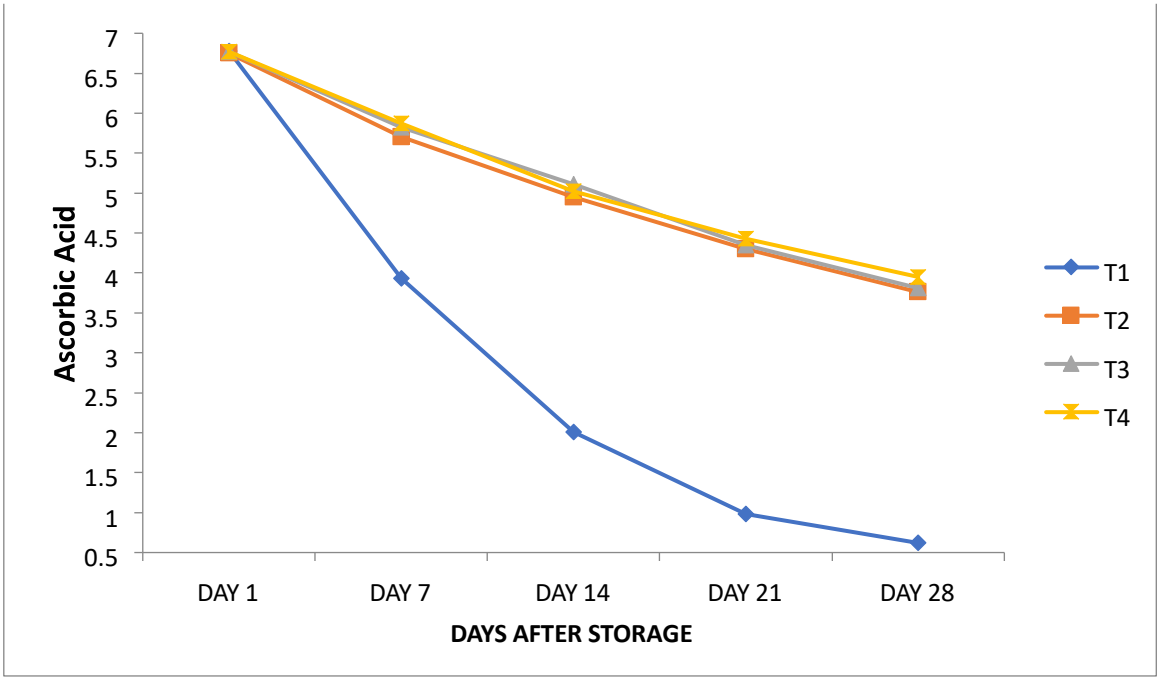

Fig. 4.5 Variation in ascorbic acid of different treatments of tender coconut water

4.2.5 Changes in mineral compositions

Sodium and potassium were found higher in control T1. sodium is lower in sample T2, and potassium is lower sample T4. Magnesium is higher for sample T2 and lower for sample T4. Calcium is higher for sample T2 and lower for sample T4. There is only slight change in minerals comparing T2, T3, T4 with T1. similar slight decrease in minerals was observed by Rajashri *et al* (2022).

Table 4.6 Mineral composition of tender coconut water at TMPs

Treatments	Minerals ppm			
	Na	K	Mg	Ca
T1	6.6700	2114.75	70.7125	145.625
T2	4.2500	1805.25	80.2500	185.750
T3	6.3400	1769.50	76.1375	165.500
T4	6.1100	1347.50	68.3000	132.375

T1 –control; T2 – microfiltration (0.1 µm, 5psi); T3 – microfiltration (0.1 µm, 10psi); T4 – microfiltration (0.1 µm, 15psi

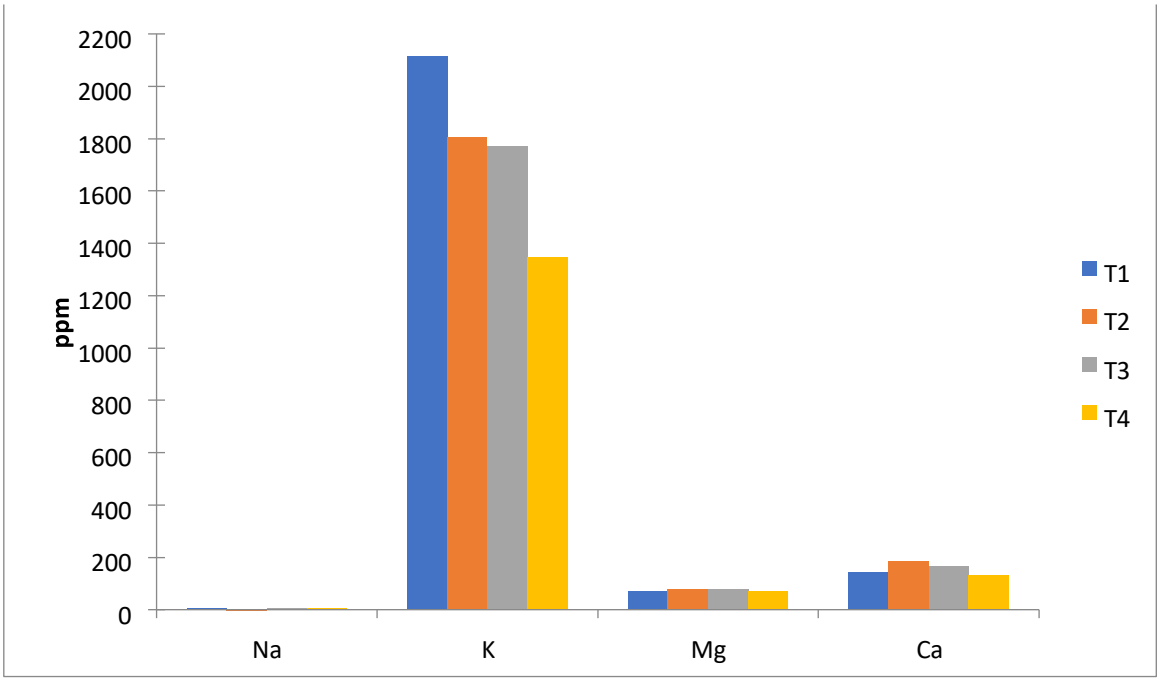

Figure 4.6 Mineral composition of tender coconut water at TMPs

4.3 CHANGES IN MICROBIOLOGICAL QUALITY OF STORED TENDER COCONUT WATER

Fungal count indicated no growth in all treated samples except in sample T1 in which it increased to 8×10^1CFU/mL on 28th day (Table 4.6 and Fig. 4.6). similar observations were made by Fernanda *et al*. (2009).

Table 4.7 Fungal count of different treatments of tender coconut water during storage

Treatments	Fungal count (CFU/mL of sample)			
	Day 1	Day 07 Day 14 Day 21		Day 28
Control (T1)	0	0 0 2×10^1		8×10^1
5psi (T2)	0	0 0 0		0
10psi (T3)	0	0 0 0		0
15psi (T4)	0	0 0 0		0

T1 –control; T2 – microfiltration (0.1 µm, 5psi); T3 – microfiltration (0.1 µm, 10psi); T4 – microfiltration (0.1 µm, 15psi)

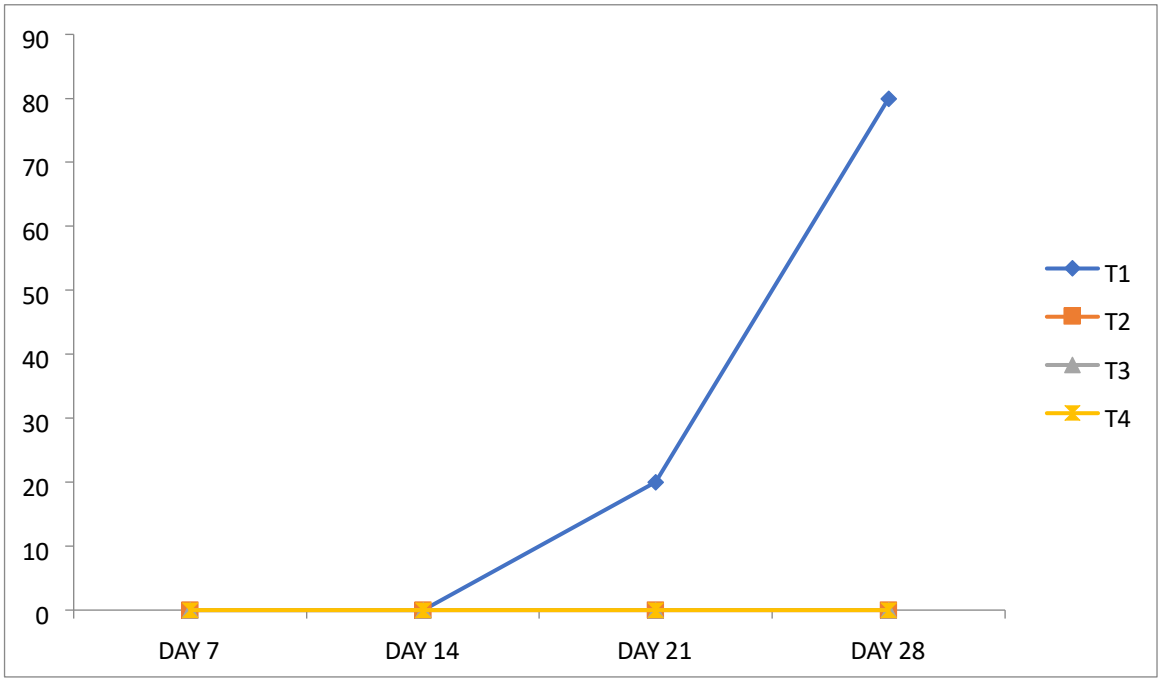

Fig. 4.7 Fungal count of different treatments of tender coconut water during storage

Bacterial count was observed to be more in treatment T1 upon storage (Table 4.7 and Fig. 4.7). Bacterial count was observed to be less for samples T2 and T3 on 7^{th} day. Initially there was no growth in all treatments. The treatment T1 have bacterial count of 10CFU/mL on 7^{th} day, after 7^{th} day storage the sample was not microbially stable. The treatment T2 have 10CFU/mL on 7^{th} day, and it increased to 4×10^{4}CFU/mL on 14^{th} day, after 14^{th} day of storage the sample was not microbially stable. The treatment T3 have bacterial count of 10CFU/mL on 7^{th} day, after 7^{th} day of storage the sample was not microbially. The treatment T4 have bacterial count of 80CFU/mL on 7^{th} day, after 7^{th} day of storage the sample was not microbially. Fernanda *et al*. (2009) reported similar microbial changes during storage in reconstituted stored coconut water.

Table 4.8 Bacterial count of different treatments of tender coconut water during storage

Treatments	Fungal count (CFU/mL of sample)				
	Day 1	Day 07	Day 14	Day 21	Day 28
Control (T1)	0	10×10^{1}	TNTC	TNTC	TNTC
5psi (T2)	0	1×10^{1}	4×10^{4}	TNTC	TNTC
10psi (T3)	0	1×10^{1}	TNTC	TNTC	TNTC
15psi (T4)	0	8×10^{1}	TNTC	TNTC	TNTC

T1 –control; T2 – microfiltration (0.1 µm, 5psi); T3 – microfiltration (0.1 µm, 10psi); T4 – microfiltration (0.1 µm, 15psi)

4.4 SENSORY EVALUATION OF TENDER COCONUT WATER SAMPLES

Sensory evaluation of treatments was carried out for consumer acceptance and preference using 15 untrained panellists selected at random. Appearance, flavour, overall acceptability of the samples was rated using a nine-point Hedonic scale where nine and one represent like extremely and dislike extremely respectively. sensory evaluation was carried out at ambient conditions in a comfortable and quiet area without disturbance under fluorescent lighting. Water was supplied to cleanse palate between samples.

Sensory quality assessed by panel of experts for establishing taste, flavour, odour, colour and appearance, and Overall acceptancy rating was also compiled (Table 4.9 and Fig. 4.8). Taste rating on hedonic for control (T1) sample is higher than T2, T3 and T4. Flavour rating on hedonic for control (T1) sample is higher than other treatments. Odour rating on hedonic for control (T1) sample is higher than other treatments. Colour and appearance rating on hedonic for control (T1) sample is lower than other treatments. Overall acceptability rating on hedonic for control (T1) sample is higher than other treatments.

Table 4.9 Rating of sensory evaluation of different treatments of tender coconut water

Treatments	Rating of sensory evaluation				
	Taste	Flavour	Odour	Colour and Appearance	Overall acceptability
Control (T1)	8	8	8	7	8
5psi (T2)	7	7	7	9	7
10psi (T3)	7	7	7	8	7
15psi (T4)	6	6	5	8	6

T1 –control; T2 – microfiltration (0.1 µm, 5psi); T3 – microfiltration (0.1 µm, 10psi); T4 – microfiltration (0.1 µm, 15psi)

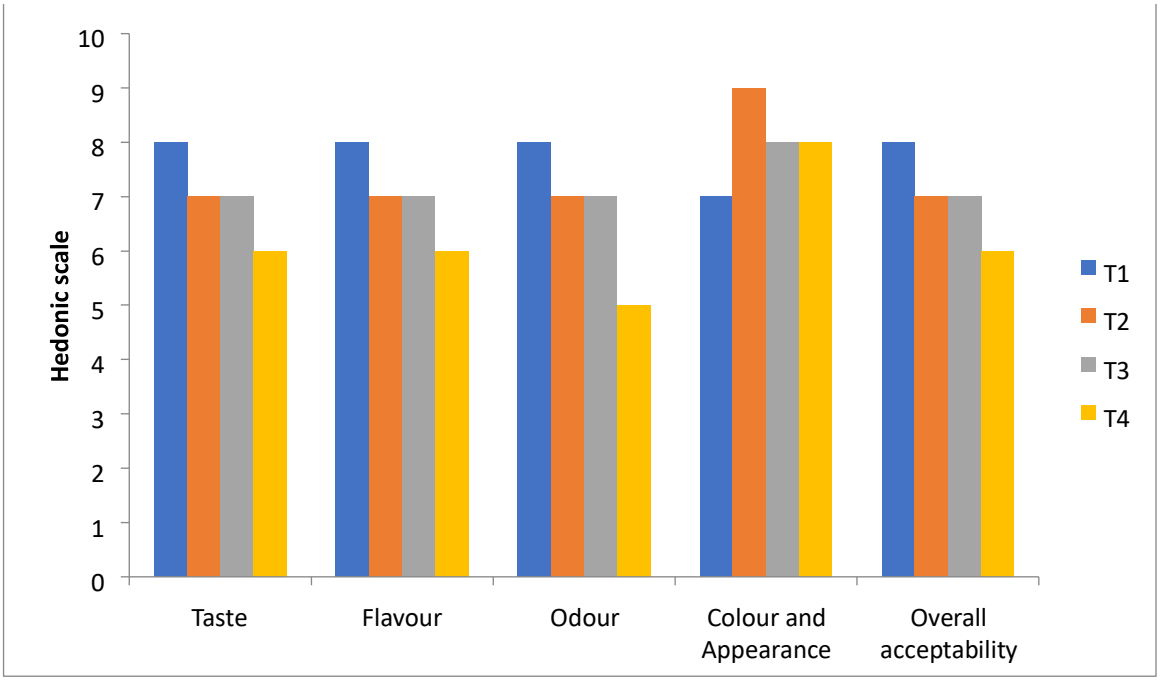

Figure 4.8 Rating of sensory evaluation of different treatments of tender coconut water

SUMMARY AND CONCLUSION

CHAPTER V
SUMMARY AND CONCLUSION

Coconut is considered a good source of energy; this is because coconut contains a large number of health benefits and nutrition which is essential to our body. Coconut contains 90 percent saturated fatty acids or 10 percent has unsaturated fatty acids. These are especially high in manganese, which is necessary for bone strength and the metabolism of carbohydrates, little cholesterol, and proteins. These are also high in iron and copper, which helps to generate red blood cells as well as antioxidants like selenium that keeps your cells protected. This refreshing and light beverage is composed of bioactive enzymes that enhance fat metabolism and aid with digestion. Also, coconut water is high in potassium balancing out the level of sodium you consume. Too much sodium in the body can result in water retention and an increase in water weight. As such coconut water aids in sweeping out extra water and toxins from the body.

Preservation by concentration to reduce water activity is one of the important food processing techniques. However, concentration using thermal processing is one of the most energy intensive processes among unit operations in the food industry.so, Membrane separation processes are promising novel alternative non-thermal and non-chemical methods that are relatively less energy intensive and retain heat labile components. Membrane separation processes are characterized by several advantages as follows: a selective barrier that causes physical separation of the chosen components without addition of any extraneous chemicals, clean and environmentally friendly technology, a lower space requirement, reutilization of by-products or waste products as secondary raw materials, decrease or elimination of processes which are not eco-compatible and optimizing the utilization of energy and water.

A study on Evaluation of microfiltration of tender coconut water was undertaken with an aim to improve the shelf life of tender coconut water. The changes in Physico-chemical, microbiological, and sensory qualities of treated

tender coconut water was assessed. Permeate flux was found decreasing as the transmembrane pressure increases. It is observed that TSS generally decreased on storage. The TSS of treatments particularly untreated TCW reduced probably more due to the conversion of carbohydrates into sugars, organic acids, and other soluble materials by metabolic processes during storage. The increase in titratable acidity was concomitant with the decrease of pH value, which could be due to the production of free acids by microbial growth. Ascorbic acid of each treatment gradually decreased with time in all treatments, it is due to the immediate reaction of an amount of ascorbic acid with the dissolved oxygen or by different mechanisms of anaerobic decomposition of ascorbic acid. There is only slight change in mineral composition for treated sample comparing to control sample. The pressure used in this process may cause some of the minerals to left behind on the membrane and another possibility is that the process of microfiltration itself may have caused a chemical reaction that resulted in the increased sodium content, the slight change in mineral content is not statistically significant. Microbial analysis indicated by fungal count revealed that, fungal growth is shown for untreated sample after 21st day and for treated sample there is no fungal growth up to 28th day. Bacterial growth for sample filtered at 5psi is microbially stable up to 14th day and all other samples are not. sensory evaluation indicated that the sample filtered at 5psiscored highest rating comparing to sample filtered at 10psi and 15psi.

It can be concluded that microfiltration treatment can be used increasing shelf life of tender coconut water without losing mineral content. After microfiltration treatment the tender coconut water becomes clearer. It is also found that the treatment done using 5psi transmembrane pressure have a better storage life. From sensory analysis it is found that this sample is having higher overall acceptability than other treated samples.

REFERENCES

CHAPTER IV

REFERENCES

AOAC 2000 Official Methods of Analysis. 17th Edition, *The Association of Official Analytical Chemists, Gaithersburg,* MD, USA. Methods 925.10, 65.17, 974.24, 992.16.

Cassano, A., Donato, L., and Drioli, E. 2007. Ultrafiltration of kiwifruit juice: Operating parameters, juice quality and membrane fouling. *J. Food Eng.*79(2): 613–621.

Darvishzadeh, T., and Priezjev, N. V. 2012. Effects of crossflow velocity and transmembrane pressure on microfiltration of oil-in-water emulsions. *J. Membrane Sci.*p 423-424, 468–476.

Fernanda, B.P., Natália, O.P., Larissa Falabella, D.F., A.N., Larissa, F.D.F., Carmo, L.S., Gomes, L.S., Regina, M.D.N. and Carlos, A.R. 2009. Microbiological testing and physical and chemical analysis of reconstituted fruit juices and coconut water. *Alimentos e Nutricao Araraquara*, 20, 523-532.

Gaddis, J. L. 1992. Effects of pressure and cross flow velocity on ultrafiltration flux . *Chemical Eng.Commun. 116(1), 153–169.*

Gunathunga, C., Abeywickrema, S. and Senaviratne Navaratne.2018 Preservation of tender coconut (Cocos nucifera L.) water by heat and UV-C treatments. *Int.J. Food Sci. and Nutri.* 3(3): 15-19

Haseena, M., Kasturi Bai, K. V., and Padmanabhan, S. 2010. Post-harvest quality and shelf-life of tender coconut. *J. Food Sci. and Technol,* 47(6), 686–689.

Hernandez, E., Chen, C. S., Shaw, P. E., Carter, R. D., and Barros, S.1992. Ultrafiltration of orange juice: effect on soluble solids, suspended solids, and aroma. *J. Agric and Food Chem.,*40(6), 986–988.

I. J. Pitt and A. D. Hocking, 2009 *Fungi and Food Spoilage*, Springer, New York, NY, USA, 3rd edition.

Laorko, A., Tongchitpakdee, S., and Youravong, W. 2013. Storage quality of pineapple juice non-thermally pasteurized and clarified by microfiltration. *J. Food Eng.,* 116(2), 554–561.

M. Naik., S. CK., and A. Rawson. 2020 Tender coconut water: A review on recent advances in processing and preservation. *Food Reviews Int.* 1-22

Mahnot, N. K., Kalita, D., Mahanta, C. L., and Chaudhuri, M. K. 2014. Effect of additives on the quality of tender coconut water processed by nonthermal two stage microfiltration technique. *LWT - Food Sci. and Technol,* 59(2), 1191–1195.

Manashi, D.P., Dipankar, K., Nikhil, K.M., Charu, L.M., Manabendra, M. and Mihir, K.C. 2012. Effect of L-ascorbic acid addition on the quality attributes of microfiltered coconut water stored at 4 °C. *Innovative Food Science and Emerging Technologies*, 16, 69-79.

Panopoulos, G., Moatsou, G., Psychogyiopoulou, C., and Moschopoulou, E. 2020. Microfiltration of Ovine and Bovine Milk: Effect on Microbial Counts and Biochemical Characteristics. *Foods,* 9(3), 284.

Polydera, A. C., Stoforos, N. G., and Taoukis, P. S. (2003). Comparative shelf-life study and vitamin C loss kinetics in pasteurised and high pressure processed reconstituted orange juice. *Journal of Food Engineering*, 60, 21–29.

Priya, S.R. and Ramaswamy, L. 2014. Tender coconut water and natures elixer to mankind. *International Journal of Recent Scientific Research*, 5, 1485-1490.

Rajashri, K., Rastogi, N. K., and Negi, P. S. (2020). Non- thermal Processing of Tender Coconut Water - A Review. *Food Reviews International*, 1–22.

Rosa, M., Ricardo, O. and Sueli, B. 2012. Comparison between microfiltration and addition of coagulating agents in the clarification of sugar cane juice. *Acta Scientiarum Technology*, 34, 413-419.

Sadashivam, S. and Manickam. 2008. A Biochemical Method, New Age Publishers.3.

Sadasivam,S and Balasubraminan.1987. Practical manual in Biochemistry, Tamil Nadu Agricultural university Coimbatore.

Scott, K. 1995. *Microfiltration.* Handbook of Industrial Membranes, p 373–429.

Shuhong, J., Yalei, Z., Fangchao, Z., Zhenjia, Y., Xuefei, Z. and Huaqiang, C. 2018. Impact of transmembrane pressure (TMP) on membrane fouling in

microalgae harvesting with a uniform shearing vibration membrane system. *Algal research*, 35, 613-623

Singh, R. and Purkait, M. K. 2019. Microfiltration Membranes. *Membrane Separation Principles and Applications,* 111–146.

Wu, T. Y., Mohammad, A. W., Md. Jahim, J. and Anuar, N. 2007. Palm oil mill effluent (POME) treatment and bioresources recovery using ultrafiltration membrane*:* Effect of pressure on membrane fouling.*J.Biochem. Eng.* 35(3): 309–317.

Xiong, X., Bond, T., Saboor Siddique, M., & Yu, W. 2021. The stimulation of microbial activity by microplastic contributes to membrane fouling in ultrafiltration*. J. Membrane Sci,* 635, 119477.

Zulaikhah, ST. 2019. Health benefits of tender coconut water (TCW). *Int. J. Pharmaceutical Sci. and Res,*10(2).

EVALUATION OF MICROFILTRATION OF TENDER COCONUT WATER

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ABSTRACT OF THESIS

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ABSTRACT

This study aimed to investigate the efficacy of microfiltration as a method to improve the shelf life of tender coconut water (TCW) while maintaining its physico-chemical, microbiological, and sensory qualities. The impact of transmembrane pressure on permeate flux was evaluated, revealing a decrease in flux with increasing pressure. Storage analysis indicated a general decrease in total soluble solids (TSS) over time, potentially attributed to the conversion of carbohydrates into sugars, organic acids, and other soluble compounds during metabolic processes. The increase in titratable acidity accompanied the decrease in pH, likely due to the production of free acids by microbial growth. Ascorbic acid content gradually declined in all treatments, possibly resulting from reactions with dissolved oxygen or anaerobic decomposition mechanisms. Comparatively, there were only slight changes in mineral composition between treated and control samples. The microfiltration process may have caused some minerals to be retained on the membrane or induced chemical reactions leading to increased sodium content, though the overall change in mineral content was not statistically significant. Microbial analysis indicated fungal growth in the untreated sample after 21 days, while the treated sample remained free from fungal growth for up to 28 days. Bacterial growth was observed in the sample filtered at 5 psi up to day 14, while all other samples exhibited microbial instability. Sensory evaluation revealed that the sample filtered at 5 psi received the highest rating compared to samples filtered at 10 psi and 15 psi, indicating better overall acceptability. In conclusion, microfiltration treatment can extend the shelf life of tender coconut water without compromising mineral content. Additionally, the treatment performed using 5 psi transmembrane pressure demonstrated superior storage stability and overall acceptability in sensory analysis.