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FO-BASED INTEGRATED SYSTEM FOR JUICE CONCENTRATION : SYSTEM DESIGN AND EXPERIMENTAL INVESTIGATION

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ABSTRACT

Fruit juices are concentrated using traditional methods such as dual stage vacuum evaporation. The impact of this method is to reduce the colour, eliminate the taste of fresh fruit juice, and have an unpleasant taste. In addition, the simultaneous concentration of fruit juices and preservation of nutritional and thermosensitive components poses challenges in food processing. Membrane-based treatments are a promising alternative to fruit juice concentrates. The technology of forward osmosis (FO) has garnered increasing research interest for its excellent advantages in producing high-quality concentrated juice. This work investigated a double-stage, double-cycle FO system for fruit juice concentration, examining membrane type and draw solution combinations to optimize the process. Several additives and fertilizer containing high-valence ions were evaluated to improve the feasibility of the FO process for juice concentration, using nanofiltration (NF)-like and reverse osmosis (RO)-like FO membrane with an interlayer constructed by MOF-s based nanoparticles. The prepared NF-like and RO-like FO membranes exhibited negative potential, superior hydrophilicity, and uneven crosslinking, which matched well with one selected additive ($MgSO_4$) and complex fertilizer (KCl, KH_2PO_4, NH4(H_2PO_4). Food additives and KH_2PO_4 fertilizers containing high valence negative ions are used, these properties can increase water transport. Double fertilizer is used in the draw solution, it is better to use KCL+$NH_4(H_2PO_4)$. Using a draw solution with triple fertilizer has more complete results compared to a draw solution with double fertilizer. Apart from that, the water flux value produced by the draw solution with triple fertilizer produces a small value.

***Keyword**: complex fertilizer, fruit juice, food additive, forward osmosis, RO-like I-TFC membrane.*

1. INTRODUCTION

Juices are rich in essential nutrients like vitamins and minerals and are recommended as part of daily fruit and vegetable intake in several European countries and the United States [1]. The global demand for healthy foods has led to a shift from soft drinks to fruit juices [2, 3]. Apple juice is particularly popular due to its nutritional benefits and digestive health properties [4]. Traditional heat treatments used in juice production can harm flavor and nutritional value, prompting research into advanced methods like cryogenic and sublimation concentration [3].

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Indira Inastiti Noor (2024) conducted research on Advanced Osmosis and Cycles to Achieve Juice Concentration and Agricultural Fertilization using KCl [5, 6]. Based on research conducted by Laura, et. al. (2016) the use of KCl material in the draw solution in the Forward osmosis process produces fertilizer with a high concentration of K [7].

This study investigates three types of fertilizer combinations mixed with a draw solution. Initially, the draw solution is combined with individual fertilizers (KCl, $NH_4(H_2PO_4)$, and KH_2SO_4) and then with double fertilizers (KCl + $NH_4(H_2PO_4)$ (Monoammonium phosphate) and KCl + KH_2SO_4). Sherub et al., (2007) found that mixing the draw solution with KCl + NH4(H2PO4) resulted in N levels of 0.61 g/L, P 1.35 g/L, and K 1.7 g/L, while mixing with KCl + KH_2SO_4 resulted in N 0 g/L, P 1.36 g/L, and K 3.43 g/L [8]. These combinations produced suboptimal N, P, and K levels for plants. Sherub et al., (2007) also tested a combination of KCl + $NH_4(H_2PO_4)$ + NH_4NO_3, which yielded good N, P, and K levels but was unsafe for human consumption [8]. Therefore, this study proposes replacing NH_4NO_3 with KH_2PO_4. Laura et al., (2016) indicated that KH_2PO_4 provides high levels of P and K [7]. Combining KCl, $NH_4(H_2PO_4)$, and KH_2PO_4 with the draw solution is expected to produce a balanced fertilizer mixture with safe and optimal N, P, and K levels for plants and human-consumable juice.

2. RESEARCH AND METHOD

2.1. Membrane Fabrication

This study used a handcrafted i-TFC (Interlayer Thin Film Composite) membrane with a dense PA (Polyamide) active layer as the FO (Forward Osmosis) membrane in addition to a RO-like (Reverse Osmosis) i-TFC composite membrane. A commercial PES substrate supported the TFC (Thin Film Composite) membrane, which featured a dense PA active layer and a nanomaterial interlayer for enhanced structure and functionality. ZIF-8 (Zinc nitrate) was chosen as the nanomaterial interlayer in the modified PDA (Polydopamine) solution [9]. The PDA coating process involved physical adsorption to apply a thin hydrophilic layer to the PES (Polyether Sulfone) [10] substrate, enhancing the membrane's hydrophilicity. PDA was applied in an alkaline dopamine solution, which polymerized into a cross-linked configuration that adhered to various solid surfaces. TMC (Trimenetricarbonyl Chloride) was used as the organic phase in the interfacial polymerization (IP) of MPD (m-Phenylenediamine) to create the PA layer of the TFC FO membrane. This quick method produces a RO-like layer hundreds of nanometers thick on the substrate and a PA repellent layer at the interface.

Production of metal-organic framework films on flexible substrates modified with polydopamine. PA-ZIF-8 on the flexible PES membrane surface that has been previously altered by PDA. The 0.22 um pore size commercial PES substrate was acquired from Hangzhou Special Paper Industry Co., Ltd. The preparation of ZIF-8, the PDA dispersion, the intermediate film, and the IP reaction process were the four stages of the membrane construction process.

2.2. Characterization of Draw Solution

The osmotic pressures of five solutions containing fertilizer and food additives at different concentrations were measured using a freezing-point osmometer. Moreover, a viscometer was used to measure the viscosities of apple juice and the same food additive solutions at 20±0.5°C.

2.3. Characterization of RO-like i-TFC FO membrane

This study examined the surface morphology of the RO-like i-TFC FO membrane and characterized its elemental changes using XPS. The XPS analysis detected nitrogen at a binding energy of 580 eV with a content of 13.92%, and zinc at 118 eV with a concentration of 1.47%, confirming the presence of ZIF-8 on the membrane surface. XRD analysis revealed that the membrane's crystalline structure, characterized by highly crystalline ZIF-8, remained unchanged before and after the juice concentration process. The XRD findings suggest that the ZIF-8 structure facilitates the passage of specific water molecules through the membrane's intrinsic pores.

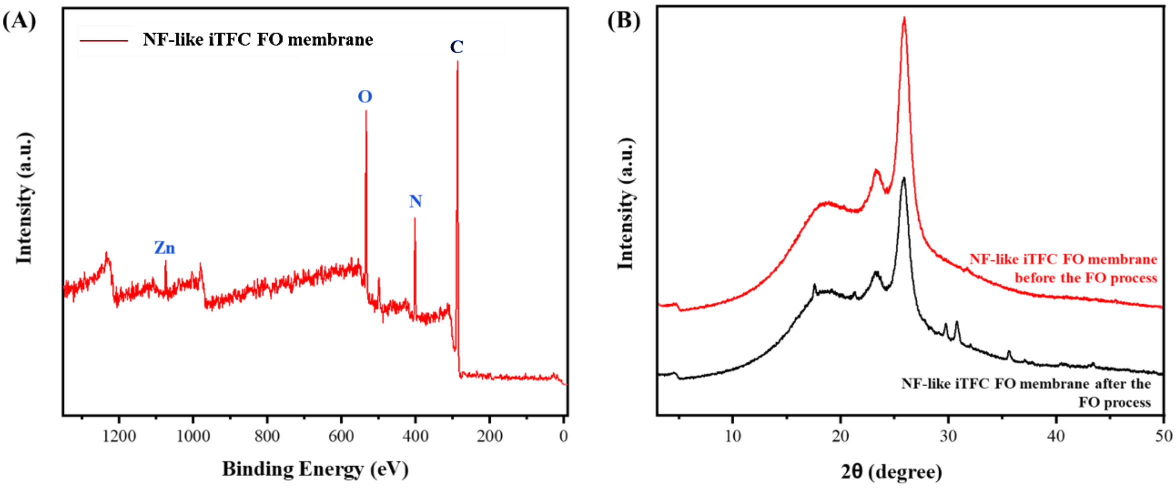

Figure 1. Elemental analysis by XPS (A) and (B) XRD analysis, RO-like i-TFC FO membrane characterization

Figure 2 shows the element distribution on the RO-like i-TFC FO membrane surface, analyzed using EDS characterization. EDS detected sulfur from the PES substrate, along with carbon, oxygen, nitrogen, and zinc from ZIF-8 in the interlayer. The PA layer's O/N ratio, which ranges from 1.0 (total cross-linking) to 1.52 (linear structure), indicated a decrease in cross-linking. In conventional desalination membranes, a thinner PA layer or nanoparticle-induced surface flaws are undesirable. However, when fertilizers are used as the draw solution, monovalent ions are blocked, allowing water passage and enhancing perm-selectivity due to the higher Donnan effect, which improves electrostatic forces and charge balance.

The goniometric approach was used to assess the hydrophilicity of the RO-like i-TFC FO membrane. A contact angle of less than 90° shows hydrophilicity, whereas a contact angle greater than 90° indicated hydrophobicity. Increasing surface roughness increases the attractive force of water, thus reducing the apparent contact angle. Due to the carboxyl group in the PA layer, the film exhibits a hydrophilic property that ensures the contact angle is less than 90°.

Zeta potential analysis quantified the membrane's surface electric potential, showing a negative charge ranging from -15 mV to -35 mV. This negative charge suggests that the membrane will exhibit a high rejection rate due to electrostatic repulsion (Donnan effect).

Consequently, a draw solution with highly charged negative ions is recommended for optimal performance.

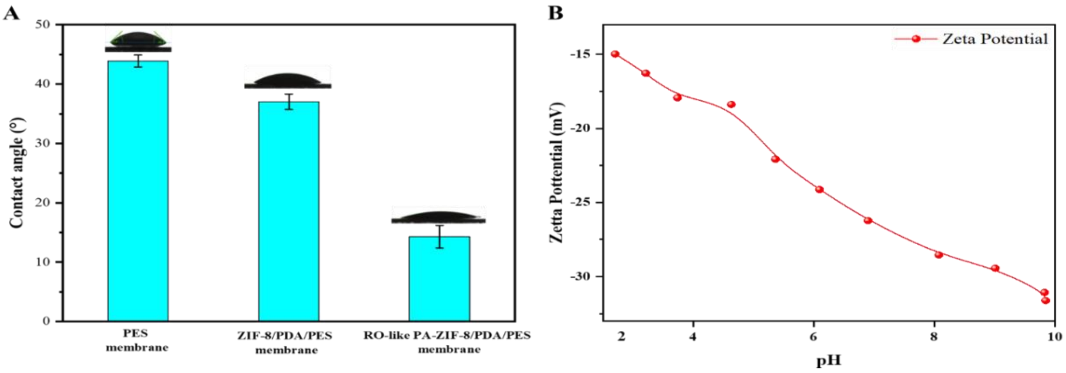

Figure 2. The contact angle (A) and zeta potential (B) of the fabricated reverse osmosis-like ion transport facilitated concentration (RO-like i-TFC) forward osmosis (FO) membrane were measured

Figure 3 displays the elements distribution on the RO-like i-TFC FO membrane surface. The elements distribution was examined by EDS characterization. EDS can identify sulfur S from the PES substrate including C, O, and N as well as zinc from ZIF-8 in the interlayer because of its detection depth, which varies from 1000 to 2000 nm. Furthermore, the PA layer's O/N ratio (which ranges from 1.0 to 2.0) reveals the degree of synthesis. For all linear models, the ratio is 1.52, and for all connections, it is 1.0. There is less connection between links in the PA layer. Thin PA layers or nanoparticle-induced flaws are typically superfluous in conventional desalination membranes. However, when fertilizers act as the DS (Draw Solution), monovalent ions will be resisted, which allows water to flow through the membrane. Moreover, using DS in conjunction with monovalent ions can enhance the generated RO-like FO membrane's perm-selectivity. This improvement is related to the higher Donnan effect that results from these ions' increased involvement in the electrostatic forces and overall charge balance.

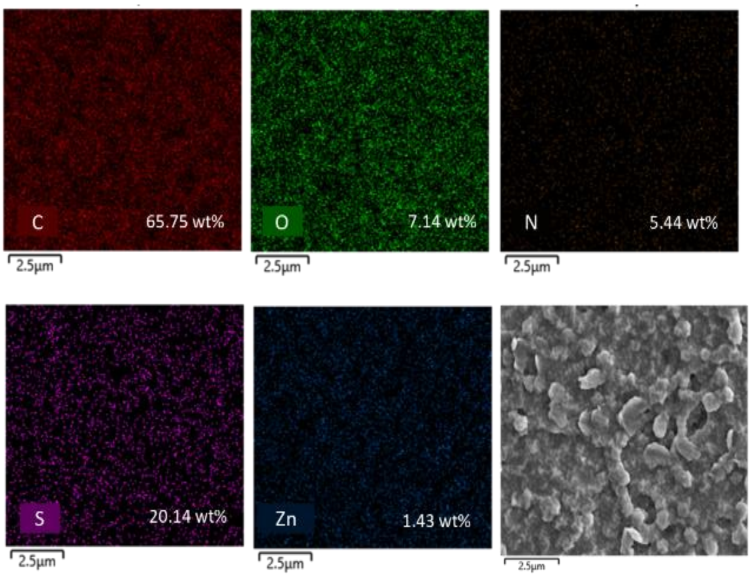

Figure 3. EDS detects the elemental distribution of the RO-like i-TFC FO membrane

Table 1. EDS detects the elemental distribution of the RO-like i-TFC FO membrane

The nature of cross-linking	C1s(%)	O1s(%)	N1s(%)	Zn1s(%)	O/N ratio	Degree of Network Cross-linking (%)
Fully cross-linked (Y=0)	75.00	12.50	12.50	0	1.00	100.00
Fully linear (X=0)	71.40	19.10	12.50	0	1.52	37.34
RO-like i-TFC FO membrane	66.65	17.96	13.92	1.47	1.29	61.98

Additionally, Figure 3 shows the AFM characterization of NF-like i-TFC membranes. Analysis shows that the surface roughness grade of the RO-like i-TFC FO membrane is 168.04 nm (Figure 3). After FO treatment (during DS concentration), the root mean square value decreased from the original roughness of the original RO-like i-TFC FO membrane (168.04 nm) to 111.05 nm. The membrane surface got smoother or less rough after being used for DS concentration through the FO process, as indicated by the decrease in rms roughness. It's possible that solute deposition influencing the membrane surface during operation is the cause of this change in surface roughness. By decreasing fouling and increasing the membrane's material-separating efficiency, the modification in surface roughness may improve membrane performance. Furthermore, a smoother surface can improve fluid flow and require less energy, improving the membrane's overall performance.

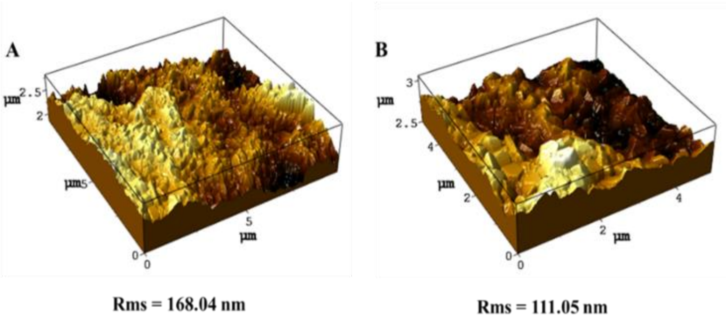

Figure 4. Structure AFM from RO-like i-TFC membrane (A) prior to the FO process and (B) following it.

3. RESULT AND DISCUSSION

3.1. Second-Stage FO System

The second stage of the second cycle of the FO system measures the difference between $MgSO_4$ (FS (Feed Solution)) and KCl (DS). Although the maximum concentration of water reaches 5 M, analysis of the first stage analysis shows that the concentration of $MgSO_4$ should be 2.5 M or less. Since KCl is DS, agreement occurs at or below 2.5 M due to $MgSO_4$ (13.48 cP) having a higher viscosity than KCl (4.2 cP). The internal concentration polarization (ICP) in the FO membrane is represented by a nonlinear relationship between the measured osmotic pressure difference and the actual flux. Low salts such as $MgSO_4$ (0.85 x 10-9 m^2/h), especially when taken in high doses, worsen ICP because they rarely have a FO membrane [11]. For this reason, high viscosities such as KCl and $MgSO_4$, which work poorly in the FO process, provide a good concentration process at 1.5 M and above.

3.2. Draw Solution for the FO System

The performance of NF-like i-TFC FO membranes can be enhanced by applying negative ions as a driving force. Five chemicals K_2SO_4, $C_6H_5K_3O_7$, $MgSO_4$, KH_2PO_4, and $C_6H_8O_7$ that are often utilized at food additive and fertilizer industries were select. The cost and caliber of these accessories were closely considered throughout the assessment. Testing was done on the physicochemical characteristics, which included compatibility with FO membranes, aqueous and chemical solubility, toxicity, and molecular weight [12]. The usefulness of five extra nutrients as solutions in the forward osmosis (FO) process was assessed analytically. These additives are appropriate for RO-like i-TFC FO membranes because of their pH range of 3.6 to 8.5 and molecular weight range of 120 to 324 daltons. Because excessive viscosity might result in internal concentration polarization (ICP), which lowers FO system performance, viscosity is crucial in guiding fluid selection [13]. Deionized water was combined with various commercial juice concentrations to remove the juice from the fruit in order to imitate fruit juice concentration. The solution's osmotic pressure determines how well the FO process works, and the measured difference shows how concentration and osmotic pressure are related.

Five additional nutrients capable of attracting liquids to the forward osmosis (FO) process were identified using a systematic review that also evaluated the effectiveness of reducing membrane fouling using the AL – FS configuration [14-16]. According to previous studies, the results showed that the increase in osmotic pressure increased rapid flow and reverse fluid flow (RSF). Compared with $MgSO_4$ and $C_6H_8O_7$, K_2SO_4, KH_2PO_4, and $C_6H_5K_3O_7$ showed the best water absorption on the FS side despite the different osmotic pressure. The solvent diffusion coefficient (D) is related to the internal concentration polarization associated with this difference. The higher diffusivity of K_2SO_4, KH_2PO_4, and $C_6H_5K_3O_7$ (2.22×10^{-9} m²/s, 1.28×10^{-9} m²/s, and 1.26×10^{-9} m²/s, respectively) compared to $MgSO_4$ (0.85×10^{-9} m²/s) [17]. The polarization effect decreases and the apparent osmotic pressure and positive osmotic pressure approach each other. Due to the smaller radius of the H^+ ions and greater ion spread, $C_6H_8O_7$ offers a higher RSF, but the importance of the H+ ions lowers the osmotic pressure, causing water to flow to the opposite side of the needed price. Within three hours, K_2SO_4, KH_2PO_4, $C_6H_5K_3O_7$, and $MgSO_4$ were better than $C_6H_8O_7$ in water extraction from FS during juice concentration, regardless of whether additives or deionized water were used [18-20].

Table 2 lists the physical and chemical property of five food additives and legal qualification. These additives are suitable with the NF-like (Nanofiltration) pH range of i-TFC FO membrane, with a molecular weight ranging from 120 to 324 Da and a pH value of 3.6 to 8.5. Table 2 explains how increased viscosity can cause internal concentration polarization (ICP) and therefore reduce the performance of the FO system. The saturated viscosities of these additives range from 1.07 to 22.07 cP; this is lower than sugar (62.86 cP) but comparable to inorganic salts such as sodium chloride (5 M, 4.92 cP) and magnesium chloride (4 M, 7.4 cP). Viscosity at saturation. The physical and chemical properties of these foods are listed in Table 2.

Table 2. Physicochemical of five food additives [7]

Food additives	Mw (Da)	Viscosity (cP, 20 °C)		Water solubility (g/100 g H_2O)	Max Solubility in water (M)	Safety limit [a] (g/kg)	Price ($/kg)
		0.5 M	Saturated concentration				
Citric Acid ($C_6H_8O_7$)	192.12	2.76	22.07	88.60	4.20	3.00	0.50
Potassium Sulfate (K_2SO_4)	174.27	1.07	1.07	8.70	0.60	0.75	0.60
Magnesium Sulfate ($MgSO_4$)	120.37	2.21	13.48	36.00	5.00	0.35	0.30
Monopotassium Phosphate (KH_2PO_4)	136.09	1.08	1.34	20.40	1.50	0.12	1.50

Furthermore, the safe limit establishes the maximum allowable solute leakage, as indicated by the following equation:

$$Limit = \frac{\underline{j_s}A}{\left(Q-\underline{j_w}A\right)\rho} \tag{6}$$

In this equation, $(\underline{j_s})/(\underline{j_w})$ represents Where Q is the juice's starting volume (L/h), Ï is the juice density (kg/L), and A is the membrane's area (m^2), and is the mean water flux (LMH) or mean return solute flux (gMH). Commercial juice was mixed with additional deionized water to produce solutions with varying juice/water volume ratios (1:1, 1:2, and 1:4). By mimicking the process of juice concentration, the objective is to extract water from the juice.

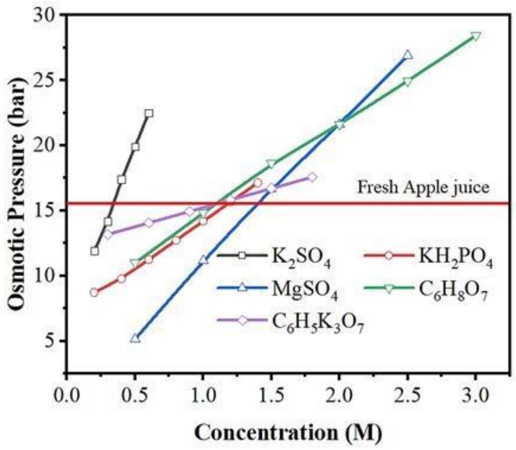

Figure 5. The figure above depicts the dependence of osmotic pressure on five additives as a function of concentration. The red line feature of osmotic pressure of pure apple juice.

This figure shows the changes in fluid outflow and return as a function of osmotic pressure when five additional nutrients are apply as draw solution (DS) and deionized water is use in drug making (FS). The osmotic pressure of additives is directly related to the increase of water flow and reverse fluid flow. According to different osmotic pressure, K_2SO_4, KH_2PO_4 and $C_6H_5K_3O_7$ showed higher water absorption capacity by FS compared to $MgSO_4$ and $C_6H_8O_7$. The internal degree of concentration polarization (ICP) results from the solvent resistance (K) in the membrane layer in contact with the technique [13]. The solvent diffusion coefficient (D) affects K solutions with higher D values over those with lower K, resulting in higher water flux. The diffusivities of K_2SO_4, KH_2PO_4, and $C_6H_5K_3O_7$ are substantially higher than that of MgSO4, with values of 2.22×10^{-9} m²/s, 1.28×10^{-9} m²/s, and 1.26×10^{-9} m²/s, respectively, compared to 0.85×10^{-9} m²/s. This weakens the polarization effect and reduces the difference between true and positive osmotic pressure.

Additionally, in the specific osmotic pressure range, $C_6H_8O_7$ showed a higher reverse fluid flow (RSF) compared to the other four additions [21]. This is due to the smaller hydration radius and higher ion diffusivity of H^+ compare to K^+ and Mg^{2+}. Preparatory to studies have shown that supplements with smaller hydrated ions generally have a higher RSF (relative solubility factor). Increased H^+ leakage causes a reduce in the effective osmotic pressure across the membrane, causing the flow rate to differ from the positive state. In contrast, $C_6H_8O_7$ is unsuitable because it leaks too much H^+, which can lead to wound contamination. This decision sheds light on the choice of $MgSO_4$ as the solution in this study.

In this study, complex fertilizers (KCl, $NH_4(H_2PO_4)$, and KH_2SO_4) were used as solvents to improve the performance of RO-like i-TFC membranes. This approach allows the direct use of diluted manure-based draw solutions in fertigation, eliminating the need to recycle and regenerate the draw process. This method gives more energy to the FO based irrigation system compared to the juice system. Although the use of liquid fertilizers in agriculture is not new, its application has attracted attention recently due to the lack of FO processes. To solve these problems and improve the FO process, RO-like i-TFC membrane was used in this study due to its high monovalent ion rejection (>99.99%).

Based on a variety of characteristics and financial factors, popular KCl fertilizers are recognized, methodically described, and assessed for their potential as FO solutes. The physical characteristics of these fertilizers are listed in Table 3.

Figure 4 shows the osmotic pressure of KCl, $NH_4(H_2PO_4)$ and KH_2SO_4 fertilizers. If the osmotic pressure of the manure is lower than that of $MgSO_4$, water transport will be poor. Therefore, the juice concentration is lower than expected. The osmotic pressure of three fertilizers at different concentrations is shown in Figure 3. The results showed that the saturated $MgSO_4$ concentration (58.2 bar) was not as high as the osmotic pressure of KCl, $NH_4(H_2PO_4)$ and KH_2SO_4 fertilizer in 1 M solution. Fresh KH_2PO_4 and $MgSO_4$ were added as shown in Tables 8 to 11. Due to their incredible capacity, RO type membranes and FO i-TFC membranes are used in the FO and PRO (Pressure Retarded Osmosis) types as seen in the second stage of the FO cycle. According to test data, PRO mode is suitable for the second stage. Using PRO mode and a KCl concentration of 0.5 M, the maximum flow rate was average (21.04 LMH) and the reverse fluid flow (RSF) was at least 0.02 mmolMH. The results also show that the flow velocity increases with altitude. Moreover, very little RSF was obtained in all transformations from the RO-like i-TFC application membrane. According to the evaluation results, the combination of the second FO treatment can be used to increase the hardness of the juice. The system contains 2.5 $MgSO_4$ (FS) and 4 M KCl (DS) and uses an i-TFC membrane similar to an RO. The results showed a flow rate of 15.04 LMH and an RSF of 0.02 mmol.

Table 3. Physicochemical of fertilizer solutions used in this study. Thermodynamic properties were determined at 1 M concentration and 25 C by using OLI STream Analyzer 3.2 [10]

Fertilizer	Mw (Da)	Viscosity (cP, 20 °C)		Water solubility (g/100 g H_2O)	Max Solubility in water (M)	Safety limit [a] (g/kg)	Price ($/kg)
		0.5 M	Saturated concentration				
Potassium Chloride (KCl)	74.55	1.4	4.2	22.40	4.60	3.00	1.74
Monoamonium Phospate ($NH_4(H_2PO_4)$)	115.03	-	-	36,90	2.5	10%	1.20
Monopotassium Phosphate (KH_2PO_4)	136.09	1.08	1.34	20.40	1.50	0.12	1.50

Table 4. Physicochemical of fertilizer solutions used in this study. Thermodynamic properties were determined at 1 M concentration and 25 C by using OLI STream Analyzer 3.2 [7]

Fertilizer	Formula	Mw (g/mol)	Osmotic Pressure (atm)	Diffusivity ($10^{-9}m^2/s$)
Potassium Chloride	KCl	74.6	44	1.79
Amonium Phospate Monobasic ($NH_4(H_2PO_4)$)	$NH_4H_2\ PO_4$	115.0	43.8	1.06
Potassium phosphate monobasic	KH_2PO_4	136.09	36.5	1.02

Table 5. The outcomes of water flux (J_w) and RSF (J_s) in the second stage of the second-cycle FO system, with 0.5 M $MgSO_4$ as FS and varying concentrations of KCl as DS, using RO-like i-TFC FO membrane, are provided

FS	0.5 M $MgSO_4$				
	KCl concentration (M)	RO-like i-TFC FO membrane			
		FO mode		PRO mode	
		J_w (LMH)	J_s (mmolMH)	J_w (LMH)	J_s (mmolMH)
DS	0.5	10.53	0.02	13.54	0.02
	1	12.04	0.02	15.04	0.02
	2	13.54	0.04	16.55	0.02
	3	15.04	0.03	19.56	0.03
	4	18.05	0.04	21.06	0.02

Table 6. The water flux (J_w) and RSF (J_s) results in the second stage of the second-cycle FO system, using 1 M $MgSO_4$ as the FS and KCl at various concentrations the DS with the application of RO-like i-TFC FO membrane, are presented in the table below:

FS	**1 M $MgSO_4$**				
	KCl concentration (M)	**RO-like i-TFC FO membrane**			
		FO mode		**PRO mode**	
		J_w **(LMH)**	J_s **(mmolMH)**	J_w **(LMH)**	J_s **(mmolMH)**
DS	0.5	9.03	0.02	11.57	0.03
	1	10.53	0.02	12.04	0.02
	2	11.57	0.03	15.04	0.02
	3	15.04	0.03	16.55	0.02
	4	16.55	0.02	19.56	0.02

Table 7. The results of water flux (J_w) and RSF (J_s) in the second stage of the second-cycle FO system, using $MgSO_4$ the FS and $NH_4(H_2PO_4)$ at different concentrations as the DS with the application of RO-like i-TFC FO membrane.

Concentration $MgSO_4$	**Concentration $NH_4(H_2PO_4)$**	**FS Concentration MgSO4 0.5 & 1 M Conductifity (m_s/cm)**	**Average J_w (LMH)**	**Average J_s (mmol MH)**
0.5	0.5	35,5	1.11	0.03
	1	56,26	1.99	0.04
	1.5	72,87	2.56	0.01
	2	85,5	2.59	0.03
1	0.5	35,5	14.94	0.03
	1	56,26	18.48	0.03
	1.5	72,87	13.67	0.72
	2	85,5	1.10	0.09

Table 8. The results of water flux (J_w) and RSF (J_s) in the second stage of the second-cycle FO system, using 1 M $MgSO_4$ as the FS and KH_2PO_4 at different concentrations as the DS, with the application of RO-like i-TFC FO membranes

Concentration $MgSO_4$	**Concentration KH_2PO_4**	**FS Concentration $MgSO_4$ 0.5 M Conductifity (mS/cm)**	**Average Jw (LMH)**	**Average Js (mmol MH)**
0.5	0.5	41,00	15,26	0,01
	0.8	50,45	36,30	0,012
	1.0	59,46	36,41	0,02
	1.2	66,67	37,00	0,01
	1.4	72,42	38,40	0,02

Table 9. The results of water flux (J_w) and RSF (J_s) in the second stage of the FO system, using 1 M $MgSO_4$ as the FS and a combination of KCl + KH_2PO_4 at different concentrations as the DS, with the application of RO-like i-TFC FO membranes

Mol Start DS	Total Mol DS	Ratio	FS Concentration $MgSO_4$ 1 M Conductifity (mS/cm)	Average Jw (LMH)	Average Js (mmolMH)
0.5	1	1:1	80	0.80	0.23
	1.5	1:2	92.36	1,063	0.19
	1.5	2:1	119	1.92	0.0084
	2	2:2	128.8	1.11	0.62

Table 10. The results of water flux (J_w) and RSF (J_s) in the second stage of the second-cycle FO system, using 1 M $MgSO_4$ as the FS and a combination of KCl + $NH_4(H_2PO_4)$ at different concentrations the DS, with the application of RO-like i-TFC FO membrane

Start Mol DS	Total mol DS	Ratio	FS Concentration $MgSO_4$ 1 M Conductifity (mS/cm)	Average Jw (LMH)	Average Js (mmolMH)
0.5	1	1:1	92.59	2.50	0.05
	1.5	1:2	107.9	1.54	0.03
	1.5	2:1	130.4	2.32	0.097
	2	2:2	139.2	1.99	0.0045

Table 11. The results of water flux (J_w) and RSF (J_s) in the second stage of the second-cycle FO system, using 1 M $MgSO_4$ as the FS and a combination of KCl, $NH_4(H_2PO_4)$, and KH_2PO_4 at different concentrations as the DS, with the application of RO-like i-TFC FO membrane

Mol Start DS	Total Mol DS	Ratio	FS Concentration $MgSO_4$ 1 M Conductifity (mS/cm)	Average Jw (LMH)	Average Js (mmolMH)
0.5	1.5	1:1:1	102.6	1,95	0.00034
	2	2:1:1	145.01	1,49	0.0049
	2.5	2:2:1	148.1	2,26	0.03

4. Conclusion and Recomendation

The constructed FO i-TFC membrane RO-like PDA-modified ZIF-8 nanoparticles as the layer in between, according to membrane characterization results. If fertilizers with a high concentration of KH_2PO_4 and food additives improve the transfer of water. It is preferable to use KCL + $NH_4(H_2PO_4)$ if the draw solution contains double fertilizer. Due to the fact that the NPK content (0.61/1.35/1.7) is more complete and twofold fertilizer produces superior results. Even so, poor water flux values are produced by double fertilizer. When using a draw solution with triple fertilizer instead of double fertilizer, the results are more comprehensive. Aside from that, the draw solution with triple fertilizer yields a tiny number for the water flux value.

In this research, the pores of the membrane were too small in the RO membrane so that the particles in the middle solution were also filtered and produced fouling. Therefore, for further research it is recommended to use an NF membrane that has larger pores. Secondly, the intermediate PDA layer on the membrane must be re-characterized because it will affect the water and salt transfer process.

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