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Reducing milk allergenicity of cow, buffalo, and goat milk using lactic acid bacteria fermentation

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Reducing Milk Allergenicity of Cow, Buffalo, and Goat Milk using Lactic Acid Bacteria Fermentation

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Abstract. Cow, buffalo, and goat milk allergenicity before and after fermentation by lactic acid bacteria were studied. Skim milk, casein, and whey extract from cow, buffalo, and goat milk were fermented using *Lactobacillus helveticus* and *Lactobacillus* subsp. *bulgaricus* and cocultivation (*Lactobacillus* subsp. *bulgaricus* with *Streptococcus thermophilus*) for 12 and 18 hours. Protein patterns (SDS-PAGE) and their allergenicity (ELISA) after fermentation were analyzed. The major casein allergen, α S1-casein, was significantly degraded in the skim milk and casein fraction after fermentation at 18 hours. *Lactobacillus* subsp. *bulgaricus* was found to be the most suitable strain to reduce buffalo and goat casein allergenicity, while cocultivation performed better in cow casein. Minor degradation of whey allergens was observed in skim milk and whey extract in all three LAB strains. Therefore, to produce hypoallergenic milk products, casein is more strongly recommended. ELISA results showed that among casein sources, goat casein allergenicity was reduced extensively and considered as the best potential milk source to produce casein-free products.

Keyword: Casein allergen, fermentation, cocultivation, milk allergenicity

INTRODUCTION

Replacement of human milk with other milk sources may trigger allergic reactions.¹ Milk allergic reaction occurs when allergenic parts of proteins (epitopes) are absorbed via the intestinal tract and interact with immune cells.² Milk proteins are composed of 2.8% casein and 0.6% whey, in which among milk proteins, α S1-casein, β -lactoglobulin, and α -lactalbumin are considered major allergens.³ A study by Kapila et al.⁴ found that cow milk proteins were more allergenic than those from buffalo and goat milk. Processing of the milk may reduce allergenicity by altering their allergenic sequences.⁵ Lactic acid bacteria (LAB) have been considered to exhibit proteolytic activity towards milk proteins. In 2013, Ahmadova et al. found that *Lactobacillus helveticus* A75 effectively hydrolyzed α S1 and β -casein, which decreased their IgE binding ability.⁶ *Lactobacillus delbrueckii* subsp. *bulgaricus* fermentation also showed activity towards epitope alteration of β -lactoglobulin.⁷ Furthermore, the cocultivation of *Streptococcus thermophilus* with LAB has been proven to reduce β -lactoglobulin allergenicity.⁸ Based on the different allergenicity potentials of cow, buffalo, and goat milk and the capability of LAB to reduce allergenicity, the present study was carried out to determine the effect of LAB fermentation on allergen degradation and allergenicity alteration from different milk sources and their fractions. The findings of this research can provide basic knowledge on the reduction of allergenicity in different milk sources and fractions using LAB fermentation, which can be further used in the dairy/food industry to produce hypoallergenic milk products.

EXPERIMENTAL DETAILS

Materials

Cow, buffalo, and goat pasteurized milk was purchased from a local supermarket in Bangkok, Thailand. Freeze-dried yogurt starter culture, *Lactobacillus helveticus*, was obtained from Clerici-Sacco, Italy. *Streptococcus thermophilus* and *Lactobacillus bulgaricus* strains were purchased from the Thailand Institute of Scientific and Technological Research (TISTR).

Casein and Whey Separation

Casein and whey were separated from pasteurized milk using a modified method from Ao and Li⁹ and Kapila, et al.⁴ Milk was defatted using centrifugation at 3000rpm at 4°C. The solid fat fraction was removed using cheesecloth and the defatted fraction was called skim milk. Skim milk was adjusted to pH 4.6 (isoelectric point of cow and buffalo casein) using 1M sodium acetate buffer (NaOAc) for cow and buffalo milk and to pH 4.2 (isoelectric point of goat casein) using 1M hydrochloric acid (HCl) for goat milk, then centrifuged at 3000 rpm for 15 minutes at 20°C. The supernatant was carefully decanted and denoted as the whey fraction, while the precipitate was collected and denoted as the casein fraction. Both of the fractions were freshly prepared prior to LAB fermentation. Protein concentration and patterns of casein and whey fractions were analyzed using the Kjeldahl method and SDS-PAGE, respectively.

Lactic Acid Bacteria Fermentation

Starter cultures from TISTR were re-activated in de-Man, Rogosa, and Sharpe (MRS) broth (OXOID Co.) for 48 hours at 37°C under anaerobic conditions prior to use. The protein concentration of the casein and whey fractions was adjusted to 4 mg/ml. The pH of the casein and whey protein fractions was adjusted with sodium bicarbonate to the pH of skim milk (pH 6.69 for cow, 6.77 for buffalo, and 6.50 for goat). Pasteurization was conducted at 75°C for 15 seconds prior to incubation with the designated starter culture. Skim milk, casein, and whey samples were fermented using *Lactobacillus helveticus* at a concentration of 5.98 µg/ml according to the Clerici-Sacco company recommendation (*Lactobacillus bulgaricus* at a concentration 2.2×10⁵ CFU/ml) and the cocultivation of *Lactobacillus bulgaricus* (2.2×10⁵ CFU/ml) with *Streptococcus thermophilus* (1.8×10⁵ CFU/ml). Fermentation of the samples was conducted at 37°C for 12 and 18 hours. Protein patterns were obtained by SDS-PAGE and allergenicity was elaborated using sandwich ELISA.

SDS-PAGE

SDS-PAGE assay was conducted according to the method of Laemmli.¹⁰ Samples were mixed (1:1) with a sample buffer consisting 10% SDS, β-mercaptoethanol, glycerol, Tris pH 6.8, and bromophenol blue. The samples were boiled for 5 minutes prior to loading onto the agarose gel (4% stacking gel and 17% separating gel). Electrophoresis was run at 120 volts and stopped at nearly the end of the glass plate. The gel was stained for 2 hours and followed by destaining.

ELISA

ELISA was performed using a casein sandwich ELISA kit from Morinaga, Inc., Japan. The method was conducted according to the manufacturer's protocol. Diluted samples and standards were added into an antibody-coated microplate and then incubated for 1 hour at room temperature. Unbound antibodies were removed by washing 6 times with 300 µl washing solution before enzyme-conjugated antibody incubation. Enzyme-conjugated antibody (100 µl) was added to each well and incubated for 30 minutes at room temperature. The wells were washed again 6 times using 300 µl washing solution. Enzyme substrate (100 µl) was then added per well to start the reaction for a duration of 20 minutes at room temperature in the dark. The reaction was stopped by adding 100 µL stopping solution. The allergenicity was determined by measuring the absorbance using a microplate reader (TECAN model

Infinite M200 Pro) at 450 nm. The allergen content of the samples was quantified using the formula below (Morinaga, Inc., Japan).

$$\text{Allergen content (ppm)} = (\text{observed value (ppb)} \times \text{dilution factor of the samples}) / 1000$$

Statistical Analysis

Data were analyzed using SPSS for Windows followed by an analysis of variance (ANOVA) one-way linear model. All experiments were performed with at least two replicates. Mean comparisons were performed using the Duncan test and the significance level was defined for $p < 0.05$.

RESULT AND DISCUSSION

Protein concentration of casein and whey extract from cow, buffalo and goat milk were analyzed as shown in Table 1. The casein extract from cow milk presented the highest protein concentration compared to the other two milk sources, although it was not statistically different ($p < 0.05$). Whey protein from goat milk was significantly higher than that from cow and buffalo milk. Fox and Sweeney¹¹ and Hussain et al.¹² stated that cow, buffalo, and goat casein protein concentrations were 2.8, 3.7, and 2.5%, respectively. However, the milk protein content can vary depending upon genetics, environment, and feed.¹³ Nonetheless, SDS-PAGE results showed that the casein extract from cow, buffalo, and goat milk protein patterns were different (Figure 1), and different amounts of α - and β -casein could be found in all milk samples. Both α - and β -casein were equally present in cow and buffalo casein, while the presence of β -casein was higher than α -casein in goat milk. Bramanti et al.¹⁴ and Kapila et al.⁴ reported that the goat casein fraction was composed of β -casein (63±11%), while α S1, γ , and κ -casein contributed 10±6, 18±4, and 8±2%, respectively. Cow and buffalo casein exhibited a high content of both α -casein (45.4 and 44.8%) and β -casein (35.2 and 35.8%).^{14,4} Similar protein patterns were found in cow, buffalo, and goat whey. The major whey protein fractions in all milk sources were found to be β -lactoglobulin, α -lactalbumin, and serum albumin.¹⁵

TABLE 1. Protein concentration of extracted casein and whey from cow, buffalo, and goat milk.

Milk Sources	Casein (g/100ml)*	Whey (g/100ml)*
Cow	2.75±0.11 ^a	0.51±0.02 ^b
Buffalo	2.57±0.21 ^a	0.27±0.04 ^c
Goat	2.41±0.11 ^a	0.63±0.00 ^a

*Values are a mean of two replications in which different letters in the same column are significantly different ($p < 0.05$).

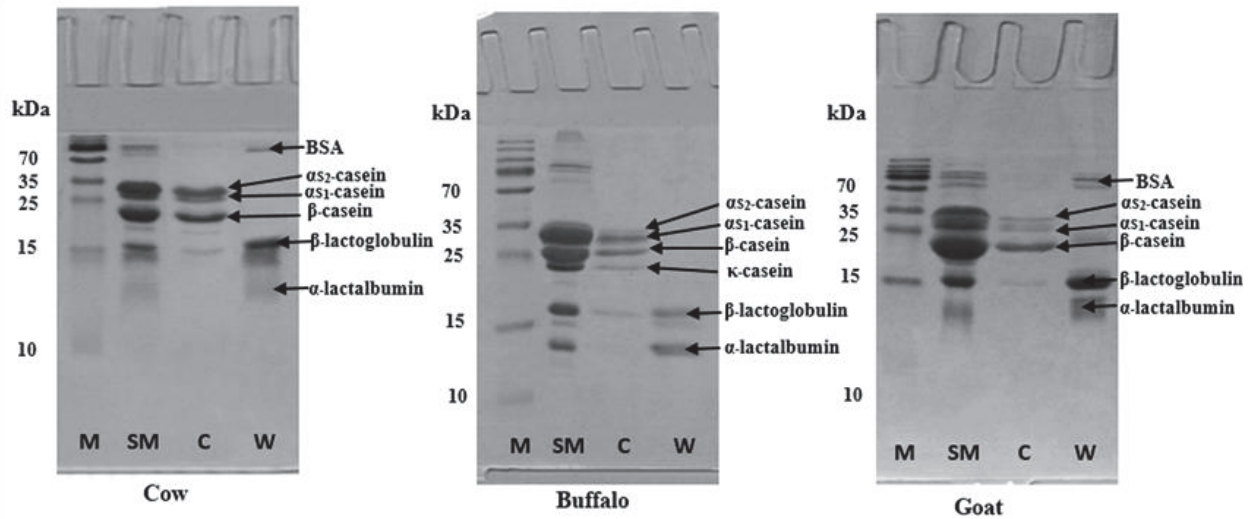


FIGURE 1. Protein patterns of skim milk (SM), casein (C), and whey (W) from cow, buffalo, and goat milk. M is protein marker.

Skim milk from cow, buffalo, and goat milk were fermented with *Lactobacillus helveticus*, *Lactobacillus delbrueckii* subsp. *bulgaricus*, and a cocultivation of *Lactobacillus delbrueckii* subsp. *bulgaricus* with *Streptococcus thermophilus* for 12 and 18 hours. Partial degradation of casein and whey proteins in cow, buffalo, and goat skim milk was observed only in the *Lactobacillus delbrueckii* subsp. *bulgaricus* fermentation. In contrast, no protein degradation was found in all the skim milk fermented by *Lactobacillus helveticus* and cocultivation of *Lactobacillus delbrueckii* subsp. *bulgaricus* with *Streptococcus thermophilus* (data not shown). Interestingly, the degradation was more predominant in casein than in the whey proteins (Figure 2).

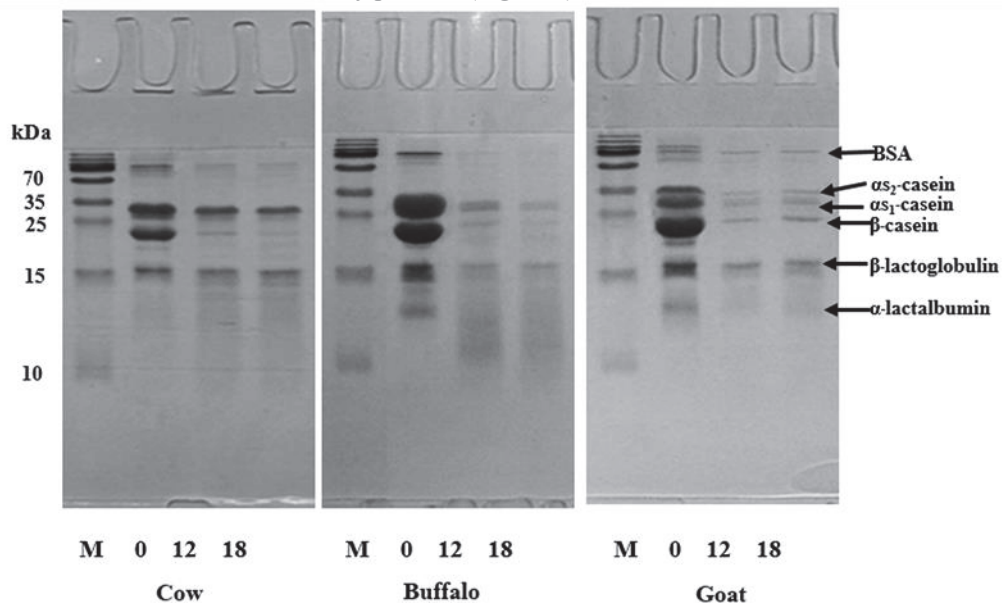


FIGURE 2. Degradation of proteins from cow, buffalo, and goat skim milk after fermentation with *Lactobacillus delbrueckii* subsp. *bulgaricus* for 12 and 18 hours. 0 indicates unfermented samples and M is protein marker.

Complete degradation can be observed in casein extract from cow, buffalo, and goat milk after fermentation with *Lactobacillus delbrueckii* subsp. *bulgaricus* and its cocultivation with *Streptococcus thermophilus* (Figure 3). This result is in accordance with casein protein degradation in skim milk. Extension of the fermentation time from 12 to 18 hours showed further degradation, especially of α 1-casein, which is considered a major casein allergen. Among

the three casein sources, the one from cow milk was fully degraded by all three LAB strains (Figure 3). In contrast, this was not the case for the whey fraction from all sources, which showed no degradation of β -lactoglobulin and α -lactalbumin after 18 hours incubation with *Lactobacillus delbrueckii* subsp. *bulgaricus* (data not shown). Similar results were found in *Lactobacillus helveticus* and its cocultivation (data not shown).

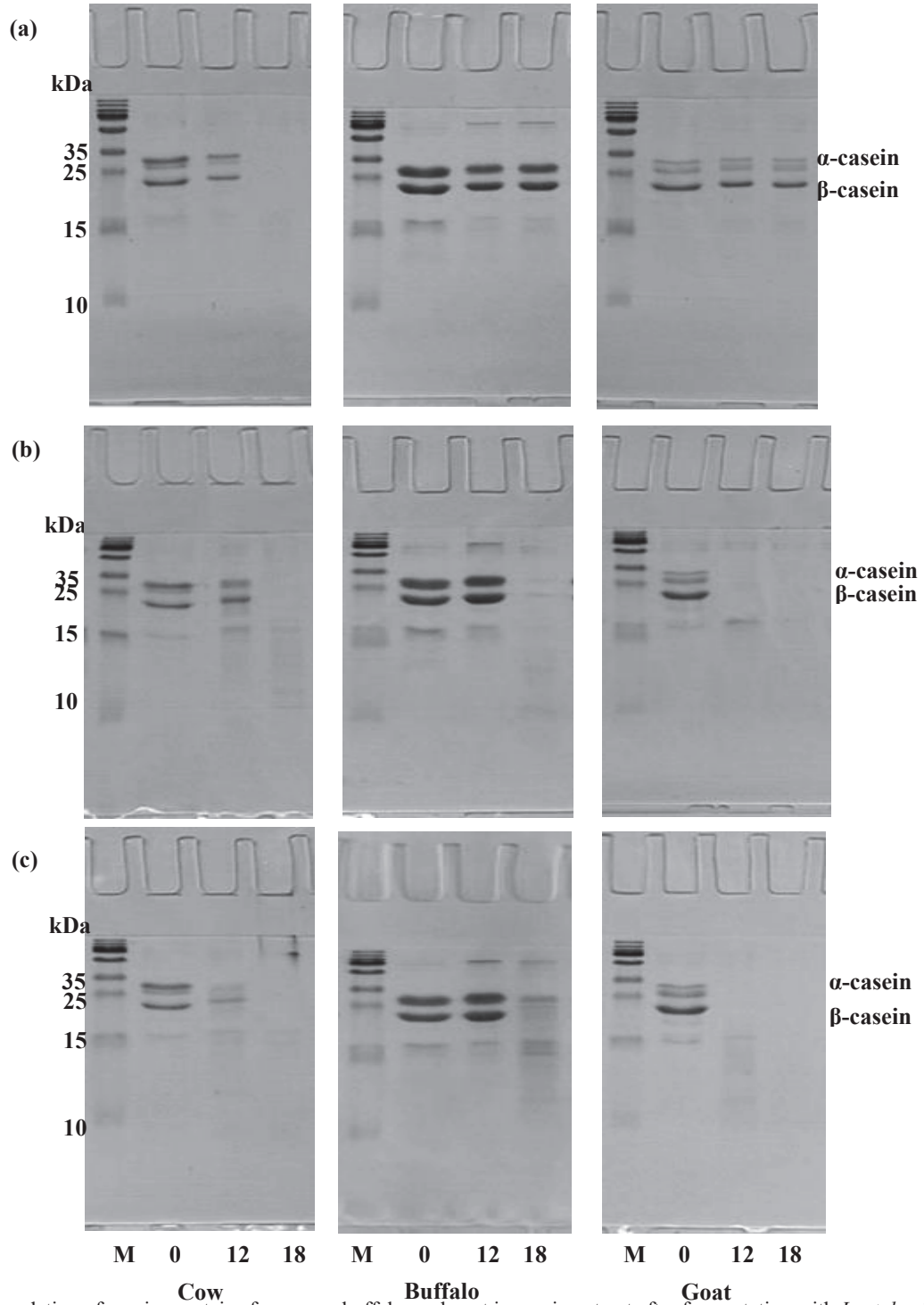


FIGURE 3. Degradation of caseins proteins from cow, buffalo, and goat in casein extract after fermentation with *Lactobacillus helveticus* (a), *Lactobacillus delbrueckii* subsp. *bulgaricus* (b), and cocultivation of *Lactobacillus delbrueckii* subsp. *bulgaricus* with *Streptococcus thermophilus* (c) for 12 and 18 hours. 0 indicates unfermented samples and M is a protein marker.

Many studies have demonstrated that *Lactobacillus* fermentation can induce degradation of milk allergens. Several recent studies have revealed that different LAB strains can reduce the antigenic properties of milk proteins. Pescuma et al.¹⁶ showed that *Lactobacillus delbrueckii* subsp. *bulgaricus* CRL 656 degraded pure β -lactoglobulin and its epitopes, thus reducing their recognition by the IgE of cow milk-allergic children using an ELISA competitive test. Similarly, IgE binding of cow α S1 casein and β casein can be significantly reduced by proteolytic activity of *Lactobacillus fermentum* IFO3956 and *Lactobacillus helveticus* A75.^{6,17} From our results, *Lactobacillus delbrueckii* subsp. *bulgaricus* showed the highest proteolytic activity towards casein proteins in skim milk and extracted casein compared to other strains used in this study. According to Simova and Beshkova¹⁸ and Fox and McSweeney,¹¹ protease activity of *Lactobacillus delbrueckii* subsp. *bulgaricus* is specific towards proline residues because of its importance for their growth. A high percentage of proline residues were found in α and β casein.^{11,18} In contrast, whey extract from cow, buffalo, and goat milk could not be degraded by all strains used. Furthermore, extension of incubation time to 24 hours showed no significant effect toward whey allergen degradation (data not shown). In 2015, Bu et al.¹⁹ also found no significant changes of whey protein degradation by extended incubation from 6 to 36 hours. It seems that the compact globular structure of whey protein is resistant to proteolysis.¹¹

According to SDS-PAGE results, milk allergen degradation can mainly be found in casein proteins. Therefore, ELISA was conducted to investigate allergenicity reduction in casein extract after LAB fermentation. The allergenicity of parent casein proteins were 21,478.01 \pm 0.09, 12,706.38 \pm 0.08, and 4,079.43 \pm 0.02 ppm for cow, buffalo, and goat, respectively ($p < 0.05$). Table 2 shows that goat casein was the most susceptible to LAB fermentation, especially the strain *Lactobacillus delbrueckii* subsp. *bulgaricus* and cocultivation of *Lactobacillus delbrueckii* subsp. *bulgaricus* with *Streptococcus thermophilus*. An increase of allergenicity was found in buffalo casein fermented with the cocultivation. The reduction of allergenicity in cow casein corresponds to casein protein degradation shown in SDS-PAGE, but this was not observed in the case of buffalo and goat casein.

TABLE 2. Reduction of casein allergenicity of cow, buffalo, and goat milk after 18 hours fermentation

Strains	Cow		Buffalo		Goat	
	Allergenicity (ppm)	% Reduction	Allergenicity (ppm)	% Reduction	Allergenicity (ppm)	% Reduction
Unfermented	21478.01 \pm 0.09 ^a		12706.38 \pm 0.08 ^b		4079.43 \pm 0.02 ^a	
<i>L. helveticus</i>	312.06 \pm 0.07 ^c	98.55	6947.52 \pm 0.06 ^c	45.32	85.11 \pm 0.02 ^b	97.92
<i>L. bulgaricus</i>	14136.17 \pm 0.09 ^b	34.18	1131.91 \pm 0.08 ^d	91.09	Nd	100
Cocultivation	326.24 \pm 0.04 ^c	98.48	15217.02 \pm 0.89 ^a	Nd	Nd	100

*Values are a mean of two replications in which different letters in the same column are significantly different ($p < 0.05$).

These results suggest that cow and buffalo milk may have higher allergenicity than goat milk due to a higher proportion of α S1 casein.^{14,4} Additionally, Kapila et al.⁴ found that the IgE titer value from cow milk (142.43%) was higher than buffalo and goat milk (66.26 and 17.76%, respectively). Recently, a relationship was found between the urease activity of *Streptococcus thermophilus* and enhancement of *Lactobacillus delbrueckii* subsp. *bulgaricus* growth in the milk environment.²⁰ Therefore, we hypothesized that a cocultivation of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* could better degrade milk allergens in terms of shorter incubation time and higher allergenicity reduction. Unexpectedly, cocultivation of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* only showed degradation in cow and goat casein allergens, but not in buffalo, just like *Lactobacillus delbrueckii* subsp. *bulgaricus* alone, and fermentation time was not reduced either. This may be due to competition over utilization of limited nitrogen sources that occurs during incubation.²¹ Another strain used in the study was *Lactobacillus helveticus*, which can degrade only cow casein, but not buffalo or goat casein. The explanation is related to the difference of buffalo and goat casein structures, specifically the casein micelle size and calcium concentration of buffalo and goat casein were bigger and higher than that from cow casein,²² which may affect water accessibility.²³

Our findings showed that the allergenicity of parent cow and buffalo caseins was higher than goat casein due to the presence of α S1-casein. The SDS-PAGE results showed degradation of casein allergens, leading to the observed reduction of allergenicity in all casein samples. Our study also indicated that different LAB strains exhibited different capabilities in cleaving allergens and reducing allergenicity, which might be due to two reasons: different

protease specificity and different casein structure. IgE binding of α S1-casein and β -casein can be significantly reduced by proteolytic activity of *Lactobacillus fermentum* IFO3956, *Lactobacillus helveticus* A75, and, to a lesser extent, in other *Lactobacillus* strains.^{6,17} It has also been reported that casein epitopes between species are different. Furthermore, cow, buffalo, and goat casein possess a different structure and proportion of the casein fraction, especially the major casein allergen (α S1-casein). Although similar protein patterns are shown among dairy species, they can develop different IgE responses due to the different properties of B and T cell epitopes.⁴

Our results indicated no digestibility of whey proteins because the LAB strains used might not be suitable for whey protein digestion. Low proline content in whey seems to be the reason for the low activity of our LAB strains.¹⁸ Tzvetkova et al.²⁴ showed that twenty-one *Lactobacillus* strains from traditional Bulgarian yogurts displayed different proteolytic activities toward α -lactalbumin and β -lactoglobulin, based on electrophoresis and RP-HPLC analysis. Phomraksa et al.²⁵ identified nine proteolytic bacteria from Thai traditional fermented foods and found that only the concentrated crude enzyme of *Bacillus subtilis* DB can digest β -lactoglobulin and reduce the allergenicity of β -LG.

It has been stated that the action of LAB during fermentation could decrease allergenicity by epitope alteration.¹⁹ However, it can also be the case that epitopes are buried in the hydrophobic area, and may thus be inaccessible in the native form and become accessible after the fermentation process, increasing the allergenicity.^{19,26} This may explain the increase of allergenicity of buffalo casein after fermentation with cocultivation of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* in our study. Although casein allergens were completely degraded by LAB fermentation based on SDS-PAGE results, an increase in buffalo casein allergenicity and little reduction of cow casein allergenicity occurred. Polyacrylamide gel electrophoresis (PAGE) is a broadly used laboratory technique to follow proteins or nucleic acid by size. It requires at least 1 μ g protein to obtain visible bands. The absence of SDS-PAGE bands in our case may be due to small peptides (in small amount) formed during digestion, and these peptides are not detectable by SDS-PAGE. Since IgE binding epitopes are the size of a few amino acids,²⁷ SDS-PAGE could not strongly represent the disappearance of epitopes, but rather whole molecules of allergens. Western blot analysis could be an alternative method to follow the cleavage of allergens as well as their allergenicity.

CONCLUSION

Fermentation by LAB could lead to milk allergenicity reduction. The casein fraction shows higher potential than whey to be used for developing hypoallergenic milk products. Goat casein was found to be the least allergenic compared to cow and buffalo caseins. A combination of different processing techniques may be necessary to reduce milk allergenicity, including heat treatment, enzymatic hydrolysis, and lactic acid fermentation. Although LAB fermentation has been widely reported to reduce milk allergenicity, the high possibility of neighbouring proteins formed during fermentation cannot be neglected.

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REFERENCES

1. E. I. El-Agamy, *Small Rumin. Res.* **68**, 64-72 (2007).
2. S. Kaminogawa and M. Totsuka, "Allergenicity of milk proteins," in *Advanced Dairy Chemistry*, edited by P. F. Fox, and P. L. H. M. Sweeney (Kluwer Academic/ Plenum Publisher, US, 2003), pp 647-674.
3. M. Steinhoff and A. P. Kratzin, "Allergens in milk and eggs," in *Food Allergens: Analysis Instrument and Methods*, edited by L. M. L. Nollet and A. J. van Hengel, (CRC Press, Taylor and Francis Group, US, 2011), pp. 129-152.
4. R. Kapila, P. K. Kavadi and S. Kapila, *Small Rumin. Res.* **112**, 191-198 (2013).
5. S. K. Sathe, S. S. Teuber and K. H. Roux, *Biotechnol. Adv.* **23**, 423-429 (2005).

6. A. Ahmadova, S. El-Ghaish, Y. Choiset, H. Rabesona, M. Drouet, J. M. Chobert, A. A. Kuliev and T. Haertle, *J. Food Biochem.* **37**, 491-500 (2013).
7. M. Pescuma, E. M. Hebert, T. Haertlé, J. M. Chobert and F. Mozzi, G. F. de Valdez, *J. Food Chem.* **170**, 407-414 (2015).
8. N. Kleber, U. Weyrich and J. Hinrichs, *Innov. Food. Sci. Emerg. Technol.* **7**, 233-238 (2006).
9. J. Ao and B. Li, *Food Res. Int.* **52**, 334-341 (2013).
10. U. K. Laemmli, *Nature* **227**, 680-685 (1970).
11. P. F. Fox and P. L. H. McSweeney, "Milk Proteins," in *Dairy Chemistry and Biochemistry* (Blackie Academic and Professional, London, 1998), pp. 145-239.
12. I. Hussain, J. Yan, A. S. Grandison and A. E. Bell, *J. Food Chem.* **135**, 1404-1410 (2012).
13. N. R. Council, *Designing Foods: Animal Product Options in the Marketplace* (The National Academies Press, Washington DC, 1988), pp. 384.
14. E. Bramanti, C. Sortino, M. Onor, F. Beni and G. Raspi, *J. Chromatogr. A* **994**, 59-74 (2003).
15. K. Hinz, P. M. O'Connor, T. Huppertz, R. P. Ross and A. L. Kelly, *J. Dairy Res* **79**, 185-191 (2012).
16. M. Pescuma, E. M. Hebert, H. Rabesona, M. Drouet, Y. Choiset, T. Haertlé, F. Mozzi, G. F. de Valdez and J. M. Chobert, *J. Food Chem* **127**, 487-492 (2011).
17. S. El-Ghaish, H. Rabesona, Y. Choiset, M. Sitohy, T. Haertlé and J. M. Chobert, *J. Dairy Res.* **78**, 203-210 (2011).
18. E. Simova and D. Beshkova, *INRA/EDP Sciences* **87**, 555-573 (2007).
19. G. Bu, Y. Luo, Y. Zhang and F. Chen, *J. Sci. Food Agric.* **90**, 2015-2020, (2015).
20. S. Arioli, G. D. Scala, M. C. Remagni, M. Stuknyte, S. Colombo, S. Guglielmetti, I. de Noni, E. Ragg and D. Mora, *Int. J. Food Microbiol.* **247**, 55-64. (2017).
21. E. Liu, H. Zheng, T. Shi, L. Ye, T. Konno, M. Oda, H. Shen and Z. S. Ji, *Int. Dairy J.* **56**, 141-150 (2016).
22. S Choudhary, S. Arora, A. Kumari, V. Narwal, S. K. Tomar and A. K. Singh, *J Food Sci. Technol.* **54**, 349–358 (2017).
23. S. Ahmad, F. M. Anjum, N. Huma, A. Sameen and T. Zahoor, *J. Anim. Plant. Sci.* **23**, 62-74 (2013).
24. I. Tzvetkova, M. Dalgarrondo, S. Danova, I. Iliev, I. Ivanova, J. M. Chobert and T. Haertlé, *J. Food Biochem.* **31**, 680-702 (2007).
25. P. Phomraksa, H. Nagano, T. Boonmars and C. Kamboonruang, *J. Food Sci.* **73**, 189-195 (2008).
26. J. M. Wal, *Allergy* **56**, 35-38 (2001).
27. H. Matsuo, T. Yokooji and T. Taogoshi, *Allergol. Int.* **64**, 332-343 (2015).

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Changes to the Polyisoprenoid Composition in Aging Leaves of Mangrove Plants

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Abstract. Polyisoprenoid (polyprenols or dehydrodolichols and dolichols) content and composition of four true mangrove plants namely *Excoecaria agallocha*, *Lumnitzera racemosa*, *Rhizophora apiculata*, and *R. lamarkii* were investigated with particular emphasis on leaf senescence. The distribution and occurrence of polyisoprenoids was analyzed using the two-plate thin layer chromatography (2P-TLC) method. The age of the leaves was divided into young leaf, leaf, and yellow leaf. In the leaves, the distribution of polyisoprenoid was found to show the presence of both polyprenols and dolichols. The occurrence of ficaprenols (C₅₀–C₅₅) was observed in young leaves and leaves of the mangrove samples studied. On the other hand, dolichol contents were not altered in the leaves with senescence. By contrast, longer polyprenols were found in yellow leaves of *E. agallocha*, *L. racemosa*, and *R. apiculata*. In addition, it should be noted that there were changes to the polyprenols in leaf senescence identified. Furthermore, the formation of ficaprenols, longer polyprenols, and dolichols was modulated in the mangrove plants. These findings suggest that the accumulated polyprenols in the yellow leaves may be due to the catalyzation process that converts ficaprenols into longer polyprenols.

Keywords: Chemotaxomic marker, leaf senescence, mangrove, polyprenols, two-plate thin layer chromatography

INTRODUCTION

Mangrove forests are a well-known source of phytochemical compounds, producing various secondary metabolites mostly derived from isoprenoid and polyisoprenoid alcohol.¹⁻³ Polyisoprenoids are categorized as either polyprenol or dolichol in reference to their isoprene structure. A number of studies have shown that polyprenols and dolichols are found in all living organism.¹⁻⁶

Despite the ubiquitous diversity of polyisoprenoids in the plant kingdom, few studies have focused on the physiological role of polyisoprenoid, particularly in mangroves species. Long-chain rubber-like polyisoprenoids have previously been reported in mangrove plants.⁷⁻⁸ In addition, polyisoprenoids have drawn much attention due to

their ability to alter the polyisoprenoid content of tissues and organs with age in both abiotic or biotic environments.^{2, 8-12}

Recently it has been reported that salinity can alter the polyisoprenoid content, in terms of polyprenols, dolichols, and bombiprenone in four salt-secretor and non-salt-secretor mangroves.¹³ This study aimed to describe the changes to the composition of four true mangrove plants namely *Excoecaria agallocha*, *Lumnitzera racemosa*, *Rhizophora apiculata*, and *R. lamarkii* with particular emphasis on leaf senescence, using the two-plate thin layer chromatography (2P-TLC) method.

MATERIALS AND METHOD

In this study, the polyisoprenoid was identified as dolichols (C₉₀-C₉₅) or ficaprenols (C₅₀-C₆₀) as described previously.² The determination of dehydrodolichols or dolichols was carried out in triplicate. Silica gel 60 TLC glass plates and silica RP-18 HPTLC glass plates were obtained from Merck (Darmstadt, Germany).

The aging of leaves from the mangrove plant samples was divided into young leaf, leaf, and yellow leaf. The leaves and yellow leaves of *E. agallocha*, leaves and yellow leaves of *L. racemosa*, young leaves, leaves, and yellow leaves of *R. apiculata*, and young leaves and leaves of *R. lamarkii* were collected from the Ngurah Rai Grand Forest Park, Bali, Indonesia, in June 2017. These mangrove samples were exposed to sunlight. The mean temperature in the month of sampling was 30-32°C, with a mean humidity of 75-77%. All of the samples were maintained in the freezer until used.

The separation of dolichols from dehydrodolichols was performed as describe previously.² In brief, the leaves of the four species were oven-dried at 65-70°C for 48 h. The shriveled tissue (5 g each) was wrinkled into a fine grain and submerged in a 2:1 ratio of chloroform/methanol (v/v) for 2 days. The crude lipid extract of the leaves was then saponified and dissolved with hexane.

Partition of polyprenol from dolichol was investigated by two-plate TLC.⁸ This procedure involved the development of two different plates, firstly, a silica gel plate with toluene-ethyl acetate (9:1) for 45 min as previously described.³ Then the TLC plate was developed perpendicularly to move polyprenol or dolichol to the focusing area of the reversed-phase plate. The reversed-phase plate was carried out in acetone for about 60 min. The spots of dehydrodolichols, dolichols, and standard solutions were separated, characterized with iodine vapor, and then imaged with a Canon E-470 printer. Polyisoprenoid was detected due to an association of its movement on the plate with that of standards of dolichol or dehydrodolichol, used in reversed-phase run. The dehydrodolichols and dolichols on the chromatogram plates were measured using ImageJ version 1.46r¹⁴ with the dolichol and dehydrodolichol standards as the criterions.

RESULTS AND DISCUSSION

Polyisoprenoids were observed in the four mangrove leaves namely *E. agallocha*, *L. racemosa*, *R. apiculata*, and *R. lamarkii*. The profile and presence of polyisoprenoids were analyzed using two-plate thin layer chromatography (2P-TLC) method²⁻³. Leaf aging of the mangrove plants was divided into three parts, young leaf, leaf, and yellow leaf and the different chain-lengths of polyisoprenoids were separated into polyprenols/dehydrodolichol and dolichol families. **Table 1** and **2** summarize the analytical analysis of the existence and distribution of polyprenols and dolichols, in the addition the carbon-chain lengths are also given for each family.

Table 1 illustrates the total lipid (TL) content of the leaves from the four mangrove plants ranged from 72.0 mg/g in the *E. agallocha* leaves to 916.73 mg/g in the *R. apiculata* young leaves. Additionally, the polyisoprenoid content was found to be increased in the yellow leaves for *E. agallocha*, *L. racemosa*, and *R. apiculata*, paralleled with the percentage of polyprenol compare to dolichol in the polyisoprenoid present. Overall, polyprenol was found in higher abundance than dolichol in the yellow leaves (**Table 1**).

The structural group of the polyprenols and dolichols identified in the leaves were found to classify into one previously described group, group-II.⁸ Group-I where there is prevalence of dolichols over polyprenols was not detected in any samples, and similarly, group-III, where polyprenols dominate over dolichols was also not observed. In the leaves, the distribution became one group, group-II, as they displayed the presence of both polyprenols and dolichols. In addition, the occurrence of ficaprenols (C₅₀-C₅₅) was examined in young leaves and leaves of the mangrove samples studied. Furthermore, the dolichol contents were found to not be altered in the leaves with senescence. In contrast, longer polyprenols were found in yellow leaves of *E. agallocha*, *L. racemosa*, and *R.*

apiculata. In addition, the changes to the polyprenols during leaf senescence were identified, where ficaprenols were characterized in young leaves of *R. apiculata* and *R. lamarkii* (**Table 2**). This finding is consistent with previous research where the presence of shorter polyprenols (C₅₀–C₅₅) was detected in *Acrostichum aureum* young leaves.⁸

TABLE 1. Polyisoprenoids pattern in leaf aging of mangroves

Species	Tissue	TL (mg/g dw)	PI (mg/g dw)	Pol (mg/g)	Dol (mg/g)	% in TL			% in PI		Type
						PI	Pol	Dol	Pol	Dol	
<i>E. agallocha</i>	leaves	72.0±9.5	2.4	1.5	0.9	3.4	2.1	1.3	62.3	37.7	II
<i>E. agallocha</i>	yellow leaves	766.7±11.4	8.0	5.1	2.9	1.1	0.7	0.4	63.4	36.6	II
<i>L. racemosa</i>	Leaves	120.0±12.1	6.7	3.0	3.7	5.6	2.5	3.1	44.8	55.2	II
<i>L. racemosa</i>	yellow leaves	985.4±14.6	11.5	8.3	3.2	1.2	0.8	0.3	72.2	27.8	II
<i>R. apiculata</i>	young leaves	916.3±13.6	6.3	3.1	3.2	0.7	0.3	0.3	49.2	50.8	II
<i>R. apiculata</i>	Leaves	97.0±7.8	6.1	2.6	3.5	6.3	2.7	3.6	42.8	57.2	II
<i>R. apiculata</i>	yellow leaves	832.7±11.6	7.6	3.9	3.7	0.9	0.5	0.4	51.3	48.7	II
<i>R. lamarkii</i>	young leaves	566.8±15.6	30.5	14.9	15.6	5.4	2.6	2.7	48.8	51.2	II
<i>R. lamarkii</i>	Leaves	94.0±10.0	3.8	1.8	2.0	1.2	0.57	0.63	46.8	53.2	II

nd = not detected, TL = Total lipids, PI = Polyisoprenoids, Pol = Polyprenols, Dol = Dolichols, dw = dry weight. Data are presented as mean of triplicate analyses.

The chain length of polyisoprenoids varied from tissue to tissue even in the same species and appeared to form two distinct families with dominating molecule species depending on the plant and the organ, summarized in **Table 2**.² One polyprenol family was detected in *E. agallocha* leaves (**Fig. 1a**), two polyprenols families were observed in *E. agallocha* yellow leaves, of which one had two dominant molecules species of C₅₅–C₆₀ (**Fig. 1b**). The longer chain polyprenol family was found in *L. racemosa* leaves and yellow leaves (**Fig. 2a-b**). Furthermore, shorter polyprenols with chain lengths of C₅₀–C₅₅ were detected in *R. apiculata* young leaves and leaves (**Fig. 3a-b**), and longer polyprenol with chain lengths of C₇₅–C₈₅ were observed in *R. apiculata* yellow leaves (**Fig. 3c**). Similarly, ficaprenols were also typical compounds of *R. lamarkii* young leaves and leaves (**Fig. 4a-b**).

TABLE 2. Chain lengths distribution of polyprenol and dolichol in four mangrove

Species	Tissue	(C43)	Polyprenol	Dolichol
<i>E. agallocha</i>	leaves	o	50 55 60 65	70 75 80
<i>E. agallocha</i>	yellow leaves	o	50 55 60 65 70 85 90 95 60 65 70 75 80 85 90 95 100	55 60 65 85 90 95
<i>L. racemosa</i>	leaves	o	105 110 115 120 125 130 135 140 and more 65 70 75 80 85 90 95 100	100 105 110 115 120 125 130 135 140 and more 65 70 75 80 85 90 95
<i>L. racemosa</i>	yellow leaves		105 110 115 120 125 130 135 140 and more	100 105 110 115 120 125 130 135 140 and more
<i>R. apiculata</i>	young leaves		50 55	70 75 80 85 90 95
<i>R. apiculata</i>	leaves	o	50 55	75 80 85 90 95
<i>R. apiculata</i>	yellow leaves		75 80 85	70 75 80 85 90 95
<i>R. lamarkii</i>	young leaves		45 50 55	70 75 80 85 90
<i>R. lamarkii</i>	leaves		50 55	70 75 80 85

In contrast to this observation, dolichols occur as one dolichol family depending on the mangrove species and tissue (**Table 2**). However, in case of *E. agallocha* yellow leaves, dolichols were found to form two families, both

shorter and longer dolichols (**Fig. 1b**). The presence of multiple families of polyisoprenoids in plant organs may be a product of diverse biosynthetic pathways derived at the same time or gradually depending on different conditions.²⁻³ These results indicate that the presence of shorter (ficaprenol) polyprenols, longer polyprenols, shorter dolichols, and longer dolichols are modulated separately in mangrove plants.

Accumulation of polyprenols with aging has been shown in *B. gymnorrhiza* older leaves, *Kandelia obovata* yellow leaves, *Ginkgo biloba* old leaves, *Hevea brasiliensis* old leaves, and senescing plant leaves.⁸⁻¹⁰ Additionally, the profile of polyprenol esters was found to be more complex in *L. racemosa* yellow leaves⁷. Taken together, these studies suggest that leaf senescence changes the polyisoprenoid composition in plants.

It has been proposed that accumulation of polyprenols in leaves is correlated to natural and time-dependent physiological changes.⁹ The vegetation season is also thought to enhance the polyprenol content, which then decreases at the end of the vegetation period of the leaves.⁹ Furthermore, seasonal changes as well as light has been reported to change polyprenols, which accumulate in summer and reduce in winter.¹⁵ In addition, the accumulation of polyprenols with age has been shown *in vitro*, in a plant tissue culture of *Taxus baccata* suspended cells.¹⁶

Changes to the content of polyisoprenoids in tissue and organs with senescence, and more recently salinity, have been described in mangrove seedlings.¹³ The differences observed in the predominance of dolichols over polyprenols in some plant tissues, and then polyprenols dominating over dolichols in mangroves is still unknown. Previously, it has been shown that dolichol dominates over polyprenol in *Kandelia obovata*, as well as the majority of mangrove and coastal plant species^{2-3, 8} suggesting the existence of polyprenol reductase in mangrove leaves.¹⁷⁻¹⁹ Therefore, this enzyme which activates the alteration of polyprenol to dolichol and corresponds to the human gene *SRD5A3*, may be energetically favored in *K. obovata* leaves. Furthermore, recently the incidence of three partially predicted polyprenol reductase genes have been described in the mangrove plant *K. obovata*.¹⁷⁻¹⁹

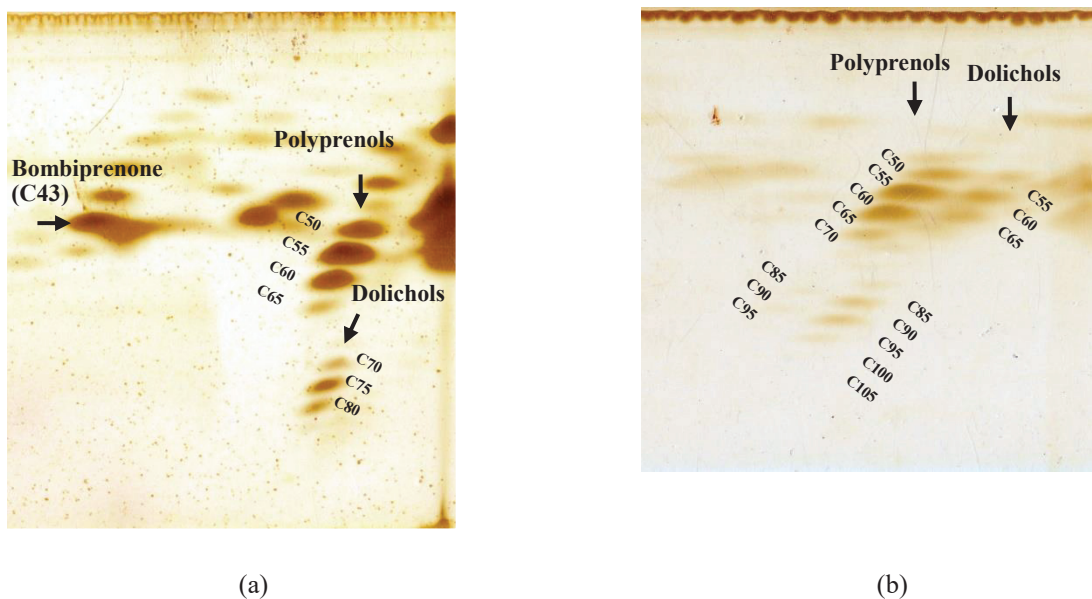
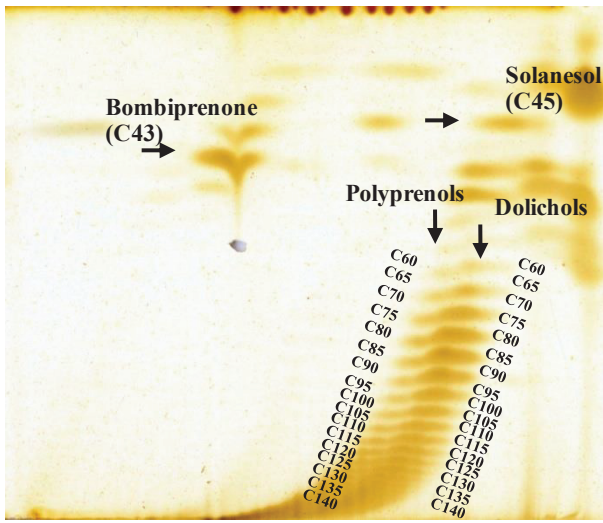
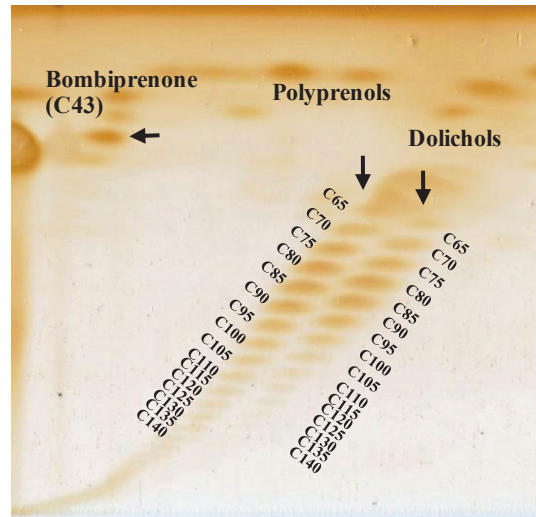


FIGURE 1. Two plate-TLC chromatograms hexane extracts of polyisoprenoids from *E. agallocha* leaves (A) and *E. agallocha* yellow leaves (B).

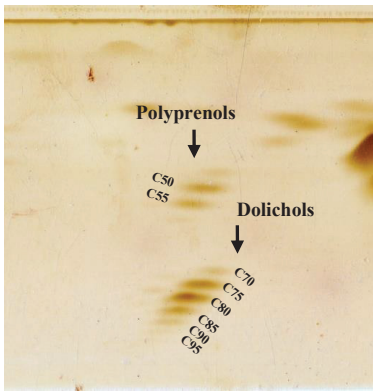


(a)

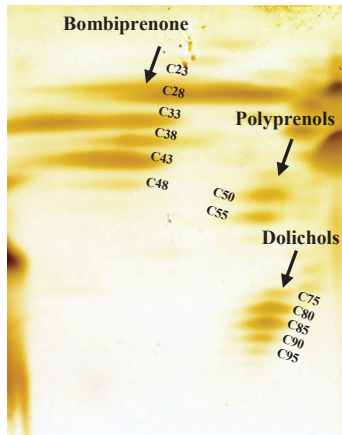


(b)

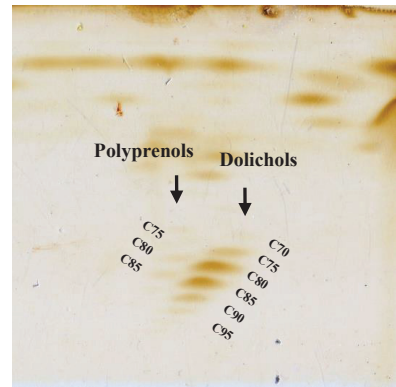
FIGURE 2. Two plate-TLC chromatograms hexane extracts of polyisoprenoids from *L. racemosa* leaves (A) and *L. racemosa* yellow leaves (B).



(a)



(b)



(c)

FIGURE 3. Two plate-TLC chromatograms hexane extracts of polyisoprenoids from *R. apiculata* young leaves (A), *R. apiculata* leaves (B), and *R. apiculata* yellow leaves (C).

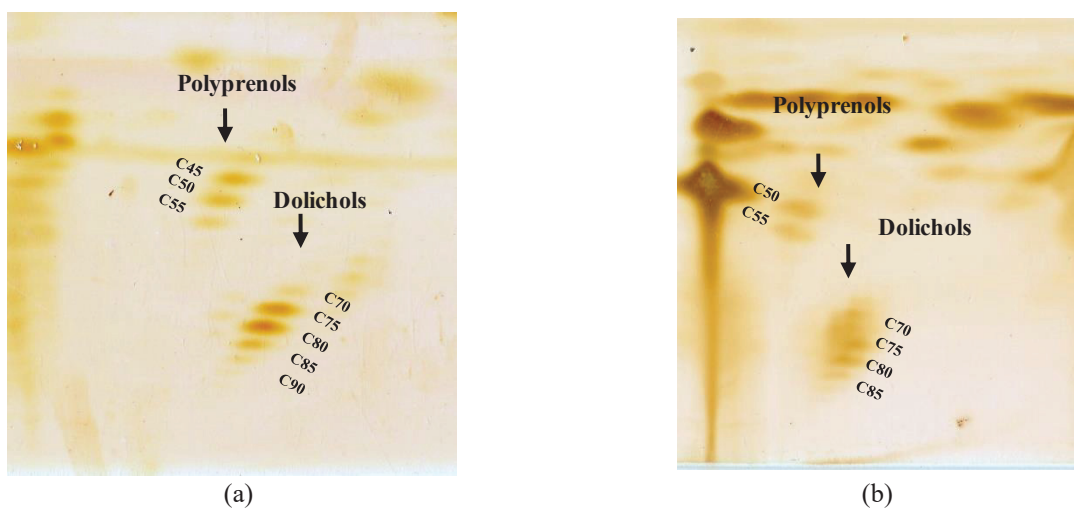


FIGURE 4. Two plate-TLC chromatograms hexane extracts of polyisoprenoids from *R. lamarkii* young leaves (A), *R. lamarkii* leaves (B).

CONCLUSIONS

This study confirmed changes to the polyprenols in leaf senescence in four mangrove plants. The formation of ficaprenols, longer polyprenols, and dolichols were also found to be modulated separately in the mangrove plants. Furthermore, these findings suggest that the accumulated polyprenols in the yellow leaves may be due to the catalyzation process needed to convert ficaprenols to longer polyprenols.

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REFERENCES

1. M. Basyuni, S. Baba, Y. Kinjo, L. A. P. Putri, L. Hakim and H. Oku, *J. Plant Physiol.* **169**, 1903–1908 (2012).
2. M. Basyuni, H. Sagami, S. Baba and H. Oku, *Dendrobiology* **78**, 18–31 (2017).
3. M. Basyuni, R. Wati, H. Sagami, Sumardi, S. Baba and H. Oku H, *Biodiversitas* **19**, 1-11 (2018).
4. S. Tateyama, R. Wititsuwannakul, D. Wititsuwannakul D, H. Sagami H and K. Ogura, *Phytochemistry*, **51**, 11–15 (1999).
5. K. Grabinska and G. Palamarczyk, *FEMS Yeast Res.* **2**, 259–265 (2002).
6. T. Ishiguro, Y. Morita-Fujimura, Y. Shidoji and H. Sagami, *Biochem. Biophys. Res. Comm.* **453**, 277–281 (2014).
7. E. Skoczylas, E. Swiezewska, T. Chojnacki and Y. Tanaka, *Plant Physiol. Biochem.* **32**, 825–829 (1994).
8. M. Basyuni, H. Sagami, S. Baba, H. Iwasaki and H. Oku, *Dendrobiology* **75**, 167–175 (2016).
9. W.J. Jankowski, E. Swizewska, W. Sasak and T. Chojnacki, *J. Plant Physiol.* **143**, 448–452 (1994).
10. S. Tateyama, R. Wititsuwannakul, D. Wititsuwannakul D, H. Sagami H and K. Ogura, *Phytochemistry* **51**, 11–15 (1999).

11. H. Zhang, K. Ohyama, J. Boudet, Z. Chen, J. Yang, M. Zang, T. Muranaka, C. Maurel, J. K. Zhu and Z. Gong, *Plant Cell* **20**, 1879–1898 (2008).
12. A. Bajda, D. Konopka-Postupolska, M. Krzymowska, J. Hennig, K. Skorupinska-Tudek, L. Surmacz, J. Wojcik, Z. Matysiak, T. Chojnacki, E. Skorzynska-Polit, M. Drazkiewicz, P. Patrzylas, M. Tomaszewska, M. Kania, M. Swist, W. Danikiewicz, W. Piotrowska and E. Swiezewska, *Physiol. Plant.* **135**, 351–364 (2009).
13. M. Basyuni, H. Sagami, S. Baba, L. A. P. Putri, R. Wati and H. Oku, *HAYATI J. Biosci.* **24**, 206–214 (2017).
14. C. A. Schneider, W. S. Rasband, K. W. Eliceiri, *Nat. Methods* **9**, 671–675 (2012).
15. A. Bajda, T. Chojnacki, J. Hertel, E. Swiezewska, J. Wójcik, A. Kaczkowska, A. Marczewski, T. Bojarczuk, P. Karolewski and J. Oleksyn, *Acta Biochim. Pol.* **52**, 233–241 (2005).
16. K. Skorupinska-Tudek, A. Pytelewska, M. Zelman-Femiak, J. Mikoszewski, O. Olszowska, D. Gajdzis-Kuls, N. Urbanska, K. Syklovska-Baranek, J. Hertel, T. Chojnaki and E. Swiezewska, *Acta Biochim. Pol.* **54**, 847–852 (2005).
17. M. Basyuni, R. Wati, H. Sagami, H. Oku and S. Baba, *J. Phys.: Conf. Ser.* **978**, 01204 (2018).
18. M. Basyuni, H. Sagami, S. Baba and H. Oku, *IOP Conf. ser.: Earth Environ. Sci.* **130**, 012039 (2018).
19. M. Basyuni and R. Wati, *J. Phys.: Conf. Ser.* **978**, 012050 (2018).

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Water Resources Management Sustainability: Review of the Simulation and Optimization Approaches

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Abstract. Sustainable development has become a big issue in almost all research fields. In water resources system management, if the system is able to satisfy the changing water demand without any system shortage, then sustainability is achieved. In fact, water resources system management is operated under complete uncertainty, with no real possibility to look into the future to predict natural condition, policy, or demand. Due to the increasing problem of scarce water resources, this encourages researchers and experts to manage water resources much more effectively, ensuring all important challenges are resolved and to maintain water resources to guarantee to meet the demand under any condition. This paper discusses the evolution of sustainable development and reviews issues regarding concept, definition, and approach to sustainable development for both research and its application to water resources system management, especially pertaining to water demand fulfillment. The paper describes state of the art simulation and optimization techniques in water resources system management, reviews the growth of simulation and optimization techniques in an effort to establish a sustainable system, frames the progress of such techniques applied to water resources system, and identifies the needs for further development to face the future challenges. This study reviews published articles from 2000 to 2017 in more than 50 peer-reviewed journals, regarding the application of simulation and optimization techniques in water resources system management in relation to sustainable water demand fulfillment by system management. The study showed that water management requires both researchers and practitioners to optimize the limited water availability in fulfillment of the increasing demand for water. Simulation and optimization are promising solutions, and as they are powered by the advancement of computer technology, they have become central to the evolution of these techniques in their application to the sustainable development of water resources system.

Keywords: optimization, simulation, sustainability, water resource management.

INTRODUCTION

At present, there are numerous reasons why there is a threat to sustainable water resources system management. These include water scarcity, risk of drought caused by conflict, poor water resources management,¹ limited and uneven distribution of water resources,² lack of good water infrastructure,³ complexity of water resources system caused by meteorological elements such as unpredictable variables like water inflow and rainfall,⁴ a rapid increase in the demand of water for irrigation, and the change in the water supply as a result of population growth.⁵ Furthermore, the situation into the future may become worse due to the impacts that the change in the climate and socio-economic may cause on the world.⁶ These conditions that will be faced by most people are becoming extremely important in ensuring the sustainability of water resources management, and therefore need more attention.

Sustainability as a concept has a long history beginning in 1713 and wasn't truly recognized until the Brundtland Report from the UN World Commission on Environment and Development (WCED) was published and widespread recognition of the sustainability concept was accepted.⁷ The Brundtland Commission defined sustainable development as infrastructure that "meets the needs of the present without compromising the ability of future generations to meet their own needs."⁸ The term 'sustainability' has since then continued to gain much attention from both the practitioner and researcher in almost every field of science. In addition, sustainability has been defined by Brundtland, to be made up of three equal elements, environment, economy, and equity.⁹ Meaning that sustainability development will only be achieved if simultaneously the environment is protected, economic growth is preserved and developed, and equity is promoted. In English verb "to sustain" has a meaning to support, to keep in being, to cause to continue in a certain state, to keep or maintain at the proper level or standard.¹⁰ In water management, necessary conditions for sustainable development are achieved when water is available in adequate quantity and quality.¹¹ Due to there being no clear accepted definition of sustainability in water resources management, Loucks proposed definition of water management sustainability is "a system designed and managed to contribute fully to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity."¹²

Presently, water resources management is facing a serious problem, with approximately 1.4 billion cubic kilometers of water available on the earth, only 2.5% is fresh water and only 0.26% of the total amount of fresh water is concentrated in lakes, reservoirs, and rivers where it is easily accessible to humans and ecosystems.¹³ In addition, the world's population in 2017 was recorded as 7.6 billion and is projected to reach 8.6 billion and 9.8 billion in 2030 and 2050, respectively.¹⁴ This population growth will certainly trigger a rapid increase in the demand for water, and there are uncertainties about how the amount of water required to meet the demand will be fulfilled. From renewable water resources only about 3900 km³ of 42000 km³ or 9.3% is available to be withdrawn for human uses. Currently, irrigation uses 27100 km³ (70%), industry uses 19%, and the municipal sector uses 11%, and it is estimated that 60% of the total water used is returned to the rivers or groundwater.¹⁵ In addition, globally over 70% of water used by the industrial (including energy), municipal, and agricultural sectors.¹⁶ In developed countries and those countries with limited water resources, water use is expected to rise by 15-35% by 2025, while developing countries where there is sufficient water resources, water use is predicted to rise by up to 200-300%.¹³

In addition to population growth and limited water resources, climate change and global warming also cause tension on water resources system management. Climate change impacts on precipitation, temperature, and evaporation can lead to further stress on water resources system, and therefore this hydrologic impact of rising of air temperature needs to be taken into consideration in water management.¹⁷

Water is a valuable resource in the world, and facing water scarcity has caused collaboration between researchers from a variety of fields including mathematics, environment, engineering, agriculture, and economics, to help solve the problem with their respective expertise. Simulation and optimization approaches provide an effective way for evaluating any design or operational policy performance that are commonly used in water resources systems evaluation.¹⁸ Currently, simulation and optimization techniques are combined in a decision support model, as to solve the problems more comprehensively. Furthermore, water resources management simulation and optimization modeling has become a modern tool due to the advancement of computer technology. Using the simulation and optimization approaches, researchers and practitioners can now make a prediction about the phenomenon more accurately and efficiently.

This paper focuses on a state of the art mathematical model approach used for water resources system optimization and simulation. The paper reviews the application of optimization and simulation in water resources problem solving and identifies the trends in water resource system modeling to offer new opportunities for further study.

RESEARCH METHODOLOGY

This study reviews the literature that has been published in peer-reviewed journals discussing the issues related to water management optimization and simulation approach methods. According to the classification scheme, more than 50 articles have been published between 2000 and 2017 established as a literature in this study. The articles have been classified by field of application (water supply management, irrigation water allocation, hydrology modeling, and reservoir operation), and reviewed by the simulation and optimization mathematical approaches used. The aim of this study was to develop a classification scheme based upon practical application, reviewing the

literature to guide the research on water management simulation and optimization approaches, and to reflect on the use of simulation and optimization approaches toward better water management sustainability development.

SIMULATION AND OPTIMIZATION APPROACHES

Optimization techniques in water resources system management are used to reach a system of optimum solutions, whereas simulation techniques approach the system evaluation by a trial and error method to lead to the identification of the best possible solution for the system.¹⁹ Simulation models have not been shown to have an ability to reach an optimal solution and optimization models have not been shown to have the capability to evaluate the system decision performance.

In water resources management, all the components of the river basin are formed as water resources system. Therefore, the system analysis is defined as “a group of methods developed for identifying, describing, and screening a system, its performance and behavior under different conditions and with different goals to be pursued.”²⁰ A number of articles have reviewed and surveyed system analysis techniques involving simulation and optimization techniques.^{21,22,23,24,25} However, the ongoing developments in the simulation and optimization techniques also affect the emergence of new methods that need to be studied further.

WATER RESOURCES MANAGEMENT OPTIMIZATION

Some efforts have been made by some countries to help face the sustainability problems in water supply, irrigation, and energy. For example, Lebanon has changed their cropping pattern to reduce agriculture water consumption and to reduce losses from the supply system through enhanced connectivity and network rehabilitation.²⁶ In addition, there has been a water allocation policy in Heihe river basin,²⁷ modification of the operating rules for the Dongwushi reservoir in China,²⁸ and Horné Orešany Reservoir in Slovakia,²⁹ construction of a dams in Italia,³⁰ and Malaysia,³¹ constructing irrigation structures in China,² inter-basin water transfer from high water availability basins to high water use basins in Iran,¹⁸ and Brazil,³² and water desalination in Egypt.³³ However, attempts to improve the water system management in terms of sustainability, without accompaniment of efforts to improve the system operation optimization, the expected goals will not be able to be achieved. With limited resources and with different constraints at each location, a mathematical approach is necessary to solve the problems.

Optimization of water resources management is important to solve and useful in case of problems with clearly defined with quantifiable objectives, describable using one or more mathematical models, analyzed through the generation of sufficient data amount, and without any obvious best alternative in practice.³⁴

Water Supply Management

A scarcity of water availability has been a trigger of conflict between the sectors that use water. With an increase to water users that is not accompanied by an increase to water sources availability requires innovation in the management of the water supply allocation. The need for water resources optimization spurs the development of various techniques in the water supply optimization to simulate the real-world system. However, the problem of water allocation is complex because it deals with constrains such as hydrology, water quality, environment, economy, and conflict among water users, therefore development of optimization techniques related to existing constrains becomes a challenge in the field of water management. Existing limitations on surface water both in quantity and quality, make the use of the groundwater source an alternative to meet the water supply demand. Although in some studies the use of ground water raises negative effects such as depletion and contamination but the exploitation of groundwater to fulfill the demand becomes inevitable.^{35,36,37,38,39,40} The use of surface and ground water simultaneously has become common in efforts to meet the water allocation demand.

Furthermore, advanced techniques have been developed for conjunctive use of surface and ground water management optimization that consider the conjunctive use between the management of the reservoir operations and the use of groundwater. Previously, a simulation/optimization model that integrated reservoir decision rules, detailed simulations of groundwater flow, conjunctive use of groundwater and surface water from reservoir to distribute through the canals has been proposed.⁴¹ Furthermore, a monthly multi-objective genetic algorithm fuzzy optimization model to maximize of irrigation releases, hydropower and satisfaction levels for existing demand in the command area has also been proposed.⁴² Previously a scenario based multistage stochastic programming model was

developed for water supply management from the highland lakes.⁴³ The objectives of the model were to maximize the expected revenue from the water and to maximize recreational benefits to support the Lower Colorado River Authority (LCRA) decision to provide water supply through inter-basin transfers in the Colorado river, by considering the uncertainty conditions in several optimization parameters. In addition, an interval-parameter multi-stage stochastic linear programming method has been developed to deal with water supply management.⁴⁴ The method was a hybrid of multi-stage stochastic programming and inexact optimization methodology, and developed for water resources decision making under uncertainty, an extension of the existing multi-stage stochastic program by examining the uncertainty of information elements.

A hybrid of integer linear programming and multi criteria analysis has been developed with the objective of optimizing the assignment of delivery schedules based on pressure, available water, pressure increase or decrease effects, number of users, delivery times and ease of sector operation criteria to apply for intermittent water supply.⁴⁵ Provided Also, an integrated framework using dynamic programming to optimize water supply system expansion combined with quadratic programming to optimize water source with short and long-term planning approach has been provided previously.⁴⁶ A DSS using mixed integer linear programming optimization has been developed to determine the most efficient operating costs of water taking delivery within the network and discussed the application of this program to South East Queensland water grid.⁴⁷ Finally, a global optimization model to maximize the water value use has been proposed, and is a supporting model tool in the decision of water allocation for environmental, urban, industrial, and agricultural areas in places of water scarcity.³⁴

To deal with the scarcity of fresh water, water treatments including desalination, filtration, and disinfection have become alternatives to fill the gap of fresh water resource availability. Previously, a mixed integer linear programming decision support model has been presented for the optimal treatment and allocation of water resources by minimization the treatment and distribution total water cost.⁴⁸ Furthermore, a multi objective goal programming model has been developed to optimize the water sources from ground water, desalinated water, and treated water to fill the predicted quantity needed during 2015 - 2050 for domestic, agricultural and industrial purposes in Riyadh.⁴⁹ In addition, a linear programming formulation has been developed as an optimization-based approach to optimize the desalination plants sizing, monthly allocation, and storage of water in Qatar.⁵⁰

Irrigation Water Allocation

Irrigation water for agriculture consumes more than 70% of the world's total water use. Therefore, a shortage of water availability affects crop production, and becomes an important factor restricting the development of the society. In this case improving irrigation water management is quite challenging as it is extremely complex. There are a number of special characteristics of irrigation management such as, the irrigation systems are ill-structured and undergo continuous evolution over time, the variability in climate directly influences the activities involved in irrigation management, the management tasks involve both quantitative and qualitative factors for decision-making (they are complex, requiring experts' knowledge), the data may not be available for making reliable decisions, there are many possible alternative solutions that must be appropriately used, large cognitive components are involved along with the computational elements, and irrigation managers are not traditionally trained in advanced methods of water management.⁵¹

There a number of mathematical optimization models that have been proposed to optimize water irrigation allocation by taking the economic benefit as a model objective function with specified water supply and planted area constraints. Firstly, a water allocation system approach that contained a linear model was presented to maximize the benefit and generate irrigation scheduling using a dynamic programming model.⁵² The optimal cropping pattern and conjunctive use of surface and ground water resources was solved by using a multilevel optimization technique, which divided the model basin into several blocks to represent the heterogeneous of the real basin characteristics and later solved the problem with a linear programming method.⁵³ Quadratic programming-based optimization has been evaluated for water allocation to maximize crop production and compared with available models for irrigation systems.⁵⁴ A robust multistage interval-stochastic method has been developed and applied to agricultural supply water policies.⁵⁵ A multi objective fuzzy linear programming irrigation model has been derived to plan the optimal cropping pattern, considering net benefit, crop/yield production, employment generation/labor requirement, and manure utilization.⁵⁶ In addition, a fuzzy linear programming (FLP) irrigation planning model was developed for the management strategies evaluation, considering net benefits, crop production, and labor employment as the objectives.⁵⁷ A similarity analysis (SA) and decision analysis (DA) has been adapted as a fuzzy logic based multi-criteria decision-making (MCDM) method and developed as a Fuzzy Decision System (FUDS) for selecting the best

performing irrigation subsystem.⁵⁸ There is an integrated genetic algorithm and irrigation planning to derive optimum cropping patterns and when it is compared with from results linear programming there are very similar.⁵⁹ A farm irrigation scheduling and simple genetic programming method has been presented as a decision support tool for irrigation project planning, in the optimization of economic profits, simulating water demand, crop yields, and estimation of crop area percentages with constraints specified by the water supply and planted area.⁶⁰ A multi-stage linear programming model has been proposed for decision support to identify optimal cropping plan decisions that maximize the farmers net return.⁶¹ A linear programming and fuzzy optimization model has been developed for planning and management of water, land, and crop system availabilities and compares the ratio of cost-benefit for each proposed farming system.⁶² Compared furthermore a comparison between the genetic algorithm, simulated annealing, and iterative improvement methods has been evaluated to optimize the economic profits, simulating water demand, and estimating the crop area percentages, with constraints specified by the water supply and planted area of an irrigation project.⁶³ It was found that all methods indicated the optimization methods performed very well and the results were very similar.

Optimization of conjunctive use, in terms of integrated use of surface and ground water resources have been widely used to achieve maximum benefit from cropping yields. Using linear programming the cropping pattern has been optimized for optimal water usage in the conjunctive use of surface and ground water.⁶⁴ In addition, a dynamic programming model has been developed for conjunctive use operating policy.⁶⁵ A conjunctive use model has been formulated to maximize the sum of the relative yields of the crops with a deterministic linear programming model.¹⁹ Furthermore, an irrigation simulation-optimization model has been developed to provide irrigation planning and management guidelines.⁶⁶ In this model, the objectives are crop harvest income, cost of irrigation water, and crop production and is optimized to maximize crop production benefits and to simulate the crop area percentage area with constraints on the minimum water supply and maximum crop area percentages. Other studies have been discussed in terms of their simulation and optimization models for conjunctive use water management previously.⁶⁷ Finally, a generic ant colony optimization simulation-optimization framework was developed to optimize the irrigation and fertilizer scheduling based on a crop growth model.⁶⁸ This has been applied in the corn production industry in eastern Colorado, where this framework was used to optimize the water available levels and fertilizer schedules.

Hydrology Modelling

Hydrology modeling is an important tool in water resource research. Hydrological model began in 1932 as a black box model, and in the 1960s conceptual and physically based model were introduced. Hydrological processes in conceptual models are expressed in the form of abstract objectives, which come from experience and physical phenomenon, therefore calibration is required for some parameters.⁶⁹ Model calibration processes are normally done by computer-based approaches or manually.⁷⁰ Previously, particle swarm optimization was used to calibrate the parameter of rainfall-runoff models and studied the impact of data length series on the calibration.⁷¹ Furthermore, the particle swarm optimization was extended to deal with multi-objectives called multi-objective particle swarm optimization by introducing the concept of Pareto rank and applied it to calibrate 13 parameters of Sacramento model of streamflow estimation.⁷² In addition, a strategy was formulated for an automatic calibration optimization procedure, based on shuffled complex evolution,⁷³ for use in solving multi-objective calibration of rainfall-runoff conceptual model parameter problems.⁷⁰

Reservoir Operation

A reservoir is an alternative to enhance the sustainability of the water resource system and has been widely chosen for a long time. Dam technology has developed to store and release surplus water in times when there are water shortages or flood control is needed. Among the single purpose dams, 48% are for irrigation, 17% for hydropower (production of electricity), 13% for water supply, 10% for flood control, 5% for recreation and less than 1% for navigation and fish farming.⁷⁴ Multipurpose dams are one of the engineering infrastructures that are important to flood control and water supply, ensuring a watershed with sufficient height and storage.⁷⁵ Since the first dam built 4000 years ago,⁷⁶ dams still have the function of preventing floods and obtaining domestic and irrigation water. In addition, dams contribution to the social and economic development of a society.⁷⁷

Optimization to solve reservoir operation problems has been extensively studied. How to optimize the water in the reservoir to fulfill the demand of the dam is a challenge for optimization models. These models need to improve the sustainability of the demand for all the dam's purposes, by considering the inflow to the reservoir. In reservoir

operation uncertainty, multi-objective function, and non-linear functions are the important features which make the computationally problems not easy to solve.

Previously, the mathematical models including linear programming, dynamic programming, and linear programming developed for reservoir operation have been reviewed.²¹ In addition, the combination solution methodology was also reviewed and assessed the merits and limitation of each of the techniques. A capability analysis of some simulation models in reservoir operation to support decisions and to choose an appropriate simulation model has been presented.²² State of the art optimization models in multi-reservoir systems have been assessed and the future directions of modeling in integrated optimization of interconnected reservoir systems considered²⁵. In this study, optimization methods and extension into multi-objective optimization, heuristic programming methods using genetic and evolutionary algorithm, artificial neural network and fuzzy rule-based system for optimization of reservoir operation were described. A simulation, optimization, and simulation-optimization combination modeling used in reservoir operation has been presented.⁷⁸ Furthermore, in this study classical optimization techniques such as linear programming, nonlinear programming, and dynamic programming were reviewed; in addition to computational intelligence techniques i.e. evolutionary algorithm, fuzzy set theory, and artificial neural network. Furthermore, the application of large-scale optimization methods related to reservoir operation techniques was also reported.

Difficulties usually faced in reservoir operation optimization, such as nonlinearity and multi-objectivity of objective function, and the uncertainty condition of future streamflow, have all triggered the modification of algorithms to deal with these conditions. Recent research on reservoir operation has developed the combination of classical optimization techniques with computational intelligence. An improvement using evolutionary algorithm namely Borg MOEA⁸⁰ to solve reservoir operation has been presented.⁷⁹ A parallel dynamic programming algorithm for multi reservoir system optimization has been developed.⁸¹ An improvement to the dynamic programming by the addition of monotonic relationship advantages between optimal release decision and reservoir storage with the concave objective function has been proposed.⁸² The latest optimization methods in reservoir operation, artificial bee colonies,⁸⁴ and the gravitational search algorithm,⁸⁵ have been reviewed and it was concluded that the computation algorithm was the most widely used in reservoir operation studies.⁸³ A multi-reservoir stochastic optimization was applied using reinforced learning and in addition a game theory method for optimizing the operation policy of reservoir for alternative framework for effective allocation has been used.^{86,87} Furthermore, variations to the particle swarm optimization⁸⁸ are used for solutions of large scale reservoir operation problem, the constrained particle swarm optimization algorithm⁸⁹ and its extension used for multi-reservoir systems,⁹⁰ and improved adaptive particle swarm optimization for the optimization of complicated dynamically constrained non-linear reservoir operation problems have been developed. A fuzzy stochastic dynamic programming approach was developed to derive operating policies of steady state multipurpose reservoirs.⁹¹ Finally, a stochastic dynamic programming model has been proposed with fuzzy storage states for optimizing the system of a reservoir operation, in which the reservoir storage volume is partitioned as a fuzzy number.⁹²

WATER RESOURCES MANAGEMENT SIMULATION

The increasing development of computer technology has directly led to the advancement in software development related to simulation. The development of the simulation technique in water resources system technology has been reviewed in its early days of its development.²² Water management modeling and hydrological modeling has become a modern tool advancing along with computer technology. Using models, researchers and engineers can make a prediction about the phenomenon more accurately and efficiently. Water management models include WEAP,⁹³ SWAT,⁹⁴ RIBASIM, MODSIM, and hydrological model including IHACRES, HEC-HMS have been widely and commonly used as a simulation tools in water resource system. The WEAP model has been applied in modeling integrated urban water management in Nepal,⁹⁵ the reliability effect of irrigation efficiency on agricultural water in Iran,⁹⁶ the impact climate change on water resources,⁹⁷ simulation of inter-basin water allocation,⁹⁸ water supply and demand in Algeria,⁹⁹ and in Pakistan.¹⁰⁰ The SWAT model has been applied in the simulation of the watershed in Argentina,¹⁰¹ in Greece,¹⁰² and in Pakistan.¹⁰³ Water management models are widely used to solve the time-mass balance, based on water allocation as the objective function.

A large number of studies have investigated the impact of climate change such as changes to such as precipitation, evaporation, temperature, on water resources system. The adaptation of the water resources system to climate change, have been modeled by simulating the water resources system and evaluating its performance. Several simulations have been conducted to look at the impacts of climate change on future water availability and

from these simulation technique,^{104,105,17} it can be seen that the water resources system needs to be modified in the future to adapt to future climate change conditions.

RESULT AND DISCUSSION

This review has presented the water availability problem and its connection to water management problems in irrigation water allocation, water supply management, and reservoir application. In addition, the use of hydrology modeling as a prediction of water availability in the hydrology cycle, and the recent simulation and optimization approaches in estimating the water resource management problems to look for sustainable solutions. As a general concept, sustainable development has been applied to the water resources industry and various sciences have continued to develop approaches and methods for the water resources management. This study has presented the application of the simulation and optimization techniques in water system management related problems

Recently, water availability become limited and this is experienced globally, but especially in developing countries. The growth of the population and the increasing water demand, compounded with global warming and climate change will lead to even more problems due to the shrinkage of available water. Water management then becomes a hope for water users as a solution to optimize the available water resources, to fulfill the water demand. The constraints of the available water and various objectives of water users are a large challenge in the management of water resources. Therefore, research must be done to develop novel methods that can be used by both researchers and practitioners.

Ineffective, inefficient management and uncertainty are the main problems in water management sustainability. Development of infrastructures without any efforts in optimizing the management operation will not contribute enough to water resources sustainability. Problem solving with simulation and optimization in water operation management have the capabilities to solve the problem in water supply, irrigation water allocation, hydrology modeling, and reservoir operation, which are the essential parts of water management that very influence to the sustainability of the water system management. The exact water supply management for various water users, the optimal allocation of irrigation water to maximize the crop production, accurate hydrological prediction by optimizing the parameters in the hydrology model, suitability of reservoir operation can all be solved using the simulation and optimization approach, ensuring the availability of water, even when constrained by limiting amount of water.

Recently, several optimization techniques have been developed and successfully applied to solve water resources system management problems. The utilization of computational intelligence algorithm models and their hybridization with classical optimization techniques has reduce common problems faced in water management optimization such as excessive computational time and the dimensionality problems. Furthermore, the combination of simulation and optimization techniques will be a great starting point in water resources system planning and management operations. As performing the preliminary water resources system optimization will reduce the time consume in simulation and the simulation technique can then be used to evaluate the system performance, which has already been optimized by the optimization algorithm procedures.

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REFERENCES

1. Y. Jiang, *J. Environ. Manage.* **90**, 3185-3196 (2009).
2. J. Wang, Y. Li, J. Huang, T. Yan and T. Sun, *Glob. Food Sec.* **14**, 9-17 (2017).
3. A. A. Gohar, S. A. Amer and F. A. Ward, *J. Hydrol.* **520**, 85-100 (2015).
4. W. H. Nam and J. Y. Choi, *Agric. Water Manag.* **142**, 115-126 (2014).
5. A. Blanke, S. Rozelle, B. Lohmar, J. Wang and J. Huang, *Agric. Water Manag.* **87**, 139-150 (2007).
6. DELTARES, (<https://www.deltares.nl/nl/>).
7. T. Kuhlman and J. Farrington, *Sustainability* **2**, 3436-3448 (2010).
8. World Commission on Environment and Development, *The Brundtland Report: 'Our Common Future,'* 13th ed., (Oxford University Press, Oxford, 1987).

9. K. E. Portney, *Sustainability* (MIT Press, 2015).
10. Murray, *The Oxford English Dictionary on Historical Principles* (Clarendon Press, Oxford, 1919).
11. Z. W. Kundzewicz, *Hydrol. Sci. J.*, **42**, 467-480 (1997).
12. D. P. Loucks, *Hydrol. Sci. J.* **42**, 513-530 (1997).
13. I. A. Shiklomanov, *World Water Resources A New Appraisal and Assessment for the 21st Century* (UNESCO, Paris, 1998).
14. United Nations, Population Division, Department of Economic and Social Affairs, *Summary for Policymakers* (United Nation, New York, 2017).
15. Food and Agriculture Organization (FAO), *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW) – Managing Systems at Risk* (Food and Agriculture Organization of the United Nations, Rome and Earthscan, London, 2011).
16. World Water Assessment Programme (WWAP), *The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk*. (UNESCO., Paris, 2012).
17. R. Zamani, A. M. Akhond-Ali, I. Ahmadianfar and N. A. Elagib, *J. Hydrol. Eng.*, **22**, 05017019 (2017).
18. M. Shourian, S. J. Mousavi and A. Tahershamsi, *Water Resour. Manag.*, **22**, 1347-1366 (2008).
19. S. Vedula, P. P. Mujumdar and G. Chandra Sekhar, *Agric. Water Manag.*, **73**, 193-221 (2005).
20. K. D. W. Nandalal and J. J Bogardi, *Dynamic Programming Based Operation of Reservoirs Applicability and Limits* (Cambridge University Press, New York, 2007).
21. W. W. Yeh, *Water Resour. Res.*, **21**, 1797-1818 (1985).
22. R. A. Wurbs, *J. Water Resour. Plan. Manag.*, **119**, 455-472 (1993).
23. C. R. Philbrick and P. K. Kitanidis, *Water Resour. Res.*, **34**, 1307-1316 (1998).
24. C. W. Dawson and R. L. Wilby, *Prog. Phys. Geogr.*, **25**, 80-108 (2001).
25. J. W. Labadie, *J. Water Resour. Plan. Manag.*, **130**, 93-111 (2004).
26. I. Alameddine, A. Fayyad, M. Abou Najm and M. El-Fadel, *Int. J. Sustain. Dev. Plan.*, **13**, 394-405 (2018).
27. Z. Wang, J. Yang, X. Deng and X. Lan, *Sustainability*, **7**, 1558-1575 (2015).
28. C. Zhang and P. Guo, *J. Hydrol.*, **553**, 735-749 (2017).
29. R. Vyleta, A. Škrinár, M. Danačová and P. Valent, in IOP Conf. Series Materials Science and Engineering **245** (Beijing, China, 2017).
30. K. N. Zeraebruk, A. O. Mayabi and J. M. Gathenya, *Environ. Nat. Resour. Res.*, **7**, 45-59 (2017).
31. E. Andre, *J. Hydrol.*, **412–413**, 246-255 (2012).
32. E. de O. Vieira and S.S. Solis, in XVI World Water Congress (2017).
33. A. Afify, *Desalination*, **250**, 928-935 (2010).
34. M. Molinos-Senante, F. Hernández-Sancho, M. Mocholí-Arce and R. Sala-Garrido, *J. Hydrol.*, **515**, 139-146 (2014).
35. T. J. Burbey, *Groundwater*, **46**, 202-211 (2008).
36. M. Giordano, *Annu. Rev. Environ. Resour.*, **34**, 153-178 (2009).
37. Y. Wada, L. P. H. van Beek, C. M. van Kempen, J. W. T. M. Reckman, S. Vasak and M. F. P. Bierkens, *Geophys. Res. Lett.*, **37**, n/a (2010).
38. H. Kulkarni, M. Shah and P. S. Vijay Shankar, *J. Hydrol. Reg. Stud.*, **4**, 172-192 (2015).
39. N. C. Dey, R. Saha, M. Parvez, S. K. Bala, A. S. Islam, J. K. Paul and M. Hossain, *Groundw. Sustain. Dev.*, **4**, 66-77 (2017).
40. F. J. Chang, C. W. Huang, S. T. Cheng and L. C. Chang, *Sci. Total Environ.*, **598**, 828-838 (2017).
41. G. Belaine, R. C. Peralta, and T. C. Hughes, *J. Water Resour. Plan. Manag.*, **125**, 154-161 (1999).
42. D. G. Regulwar and P. A. Raj, *J. Water Resour. Prot.*, **4**, 271 (2009).
43. D. W. Watkins, D. C. McKinney, L. S. Ladon, S. S. Nielsen and Q. W. Martin, *Int. Trans. Oper. Res.*, **7**, 211-230 (2000).
44. Y. P. Li, G. H. Huang and S. L. Nie, *Adv. Water Resour.*, **29**, 776-789 (2006).
45. A. E. Ilaya-Ayza, J. Benítez, J. Izquierdo and R. Pérez-García, *J. Comput. Appl. Math.*, **309**, 695-703 (2017).
46. C. C. S. Fraga, J. Medellín-Azuara and G.F. Marques, *Sustain. Cities Soc.*, **29**, 247-256 (2017).
47. S. K. Shanmugasundaram, R. Prasad and J. Fear, *Procedia Eng.*, **70**, 1524-1530 (2014).
48. D. Abdalbaki, M. Al-Hindi, A. Yassine and M. Abou Najm, *J. Clean. Prod.*, **164**, 994-1006 (2017).
49. M. Al-Zahrani, A. Musa and S. Chowdhury, *Environ. Dev. Sustain.*, **18**, 777-798 (2016).
50. S. Atilhan, A. Bin Mahfouz, B. Batchelor, P. Linke, A. Abdel-Wahab, F. Nápoles-Rivera, A. Jiménez-Gutiérrez and M.M. El-Halwagi, *Clean Technol. Environ. Policy*, **14**, 161-171 (2012).
51. S. Mohan and N. Arumugam, *Comput. Electron. Agric.*, **17**, 263-280 (1997).

52. D. Yaron and A. Dinar, *Am. J. Agric. Econ.*, **64**, 681-689 (1982).
53. G. N. Paudyal and A. Das Gupta, *J. Irrig. Drain. Eng.*, **116**, 273-291 (1990).
54. R. Wardlaw and J. Barnes, *J. Irrig. Drain. Eng.*, **125**, 345-354 (1999).
55. Y. P. Li, G. H. Huang, S. L. Nie and X. Chen, *Agric. Water Manag.*, **98**, 1577-1588 (2011).
56. D. G. Regulwar and J. B. Gurav, *Water Resour. Manag.*, **25**, 1387-1416 (2011).
57. K. S. Raju and D. N. Kumar, *ISH J. Hydraul. Eng.*, **6**, 55-63 (2000).
58. K. S. Raju and D. N. Kumar, *Irrig. Drain.*, **54**, 455-465 (2005).
59. K. S. Raju and D. N. Kumar, *Water Resour. Manag.*, **18**, 163-176 (2004).
60. S. F. Kuo, G. P. Merkley and C. W. Liu, *Agric. Water Manag.*, **45**, 243-266 (2000).
61. Á. Galán-Martín, C. Pozo, G. Guillén-Gosálbez, A. Antón Vallejo and L. Jiménez Esteller, *Land Use Policy*, **48**, 515-524 (2015).
62. B. Sahoo, A. K. Lohani and R. K. Sahu, *Water Resour. Manag.*, **20**, 931-948 (2006).
63. S. F. Kuo, C. W. Liu and S. K. Chen, *J. Am. Water Resour. Assoc.*, **39**, 59-73 (2003).
64. D. Khare, M. K. Jat and Ediwahyunan, *J. Hydrol.*, **328**, 764-777 (2006).
65. M. Karamouz, R. Kerachian and B. Zahraie, *J. Irrig. Drain. Eng.*, **130**, 391-402 (2004).
66. S. F. Kuo and C. W. Liu, *Hydrol. Process.*, **17**, 3141-3159 (2003).
67. M.A. Marino, in *IAHS-AISH Publ.* (Maastricht, Netherlands, 2001), pp. 165–173.
68. D.C.H. Nguyen, J.C. Ascough, H.R. Maier, G.C. Dandy and A.A. Andales, *Environ. Model. Softw.*, **97**, 32-45 (2017).
69. Q. Wu, S. Liu, Y. Cai, X. Li and Y. Jiang, *Hydrol. Earth Syst. Sci.*, **21**, 393-407 (2017).
70. H. Madsen, *J. Hydrol.*, **235**, 276-288 (2000).
71. C. Li, H. Wang, J. Liu, D. Yan, F. Yu and L. Zhang, *Water Sci. Eng.*, **3**, 378-393 (2010).
72. M. K. Gill, Y. H. Kaheil, A. Khalil, M. McKee and L. Bastidas, *Water Resour. Res.*, **42**, 1-14 (2006).
73. Q. Duan, S. Sorooshian and V. Gupta, *Water Resour. Res.*, **28**, 1015-1031 (1992).
74. ICOLD, (<http://www.icold-cigb.net/>).
75. C. Chaleeraktragoon and Y. Chinsomboon, *J. Hydro-Environment Res.*, **9**, 133-144 (2015).
76. G. Romanescu, A. Romanescu and G. Romanescu, in *2nd Int. Conf. - Water Resour. Wetl.* (Tulcea, Romania, 2014), pp. 485–492.
77. A. K. Biswas and C. Tortajada, *Int. J. Water Resour. Dev.*, **17**, 9-21 (2001).
78. D. Rani and M. M. Moreira, *Water Resour. Manag.*, **24**, 1107-1138 (2010).
79. J. Y. Al-Jawad and T. T. Tanyimboh, *J. Environ. Manage.*, **197**, 275-286 (2017).
80. D. Hadka and P. Reed, *Evol. Comput.*, **21**, 231-259 (2013).
81. X. Li, J. Wei, T. Li, G. Wang and W. W. G. Yeh, *Adv. Water Resour.*, **67**, 1-15 (2014).
82. T. Zhao, X. Cai, X. Lei and H. Wang, *J. Water Resour. Plan. Manag.*, **138**, 590-596 (2012).
83. A. Ahmad, A. El-Shafie, S. F. M. Razali and Z. S. Mohamad, *Water Resour. Manag.*, **28**, 3391-3405 (2014).
84. D. Karaboga, *An Idea Based On Honey Bee Swarm For Numerical Optimization* (Erciyes University, Turkey, 2005).
85. E. Rashedi, H. Nezamabadi-Pour and S. Saryazdi, *Inf. Sci. (Ny.)*, **179**, 2232-2248 (2009).
86. J. H. Lee and J. W. Labadie, *Water Resour. Res.*, **43**, 1-16 (2007).
87. K. Madani and M. Hooshyar, *J. Hydrol.*, **519**, 732-742 (2014).
88. J. Kennedy and R. Eberhart, in *Proceeding of ICNN'95 - Int. Conf. Neural Networks* (IEEE, Perth, Australia, 1995), pp. 1942–1948.
89. M. H. Afshar, *J. Hydro-Environment Res.*, **6**, 75-87 (2012).
90. M. H. Afshar, *Int. J. Electr. Power Energy Syst.*, **51**, 71-81(2013).
91. A. Tilmant, P. Fortemps and M. Vanclooster, *Water Resour. Manag.*, **16**, 1-22 (2002).
92. S. J. Mousavi, K. Mahdizadeh and A. Afshar, *Adv. Water Resour.*, **27**, 1105-1110 (2004).
93. D. Yates, J. Sieber, D. Purkey and A. Huber-Lee, *Water Int.*, **30**, 487-500 (2005).
94. J. G. Arnold, R. Srinivasan, R. S. Muttiah and J. R. Williams, *J. Am. Water Resour. Assoc.*, **34**, 73-89 (1998).
95. C. Saraswat, B. K. Mishra and P. Kumar, *Sustain. Sci.*, **12**, 1037-1053 (2017).
96. N. Zohrabi, B. N. Nassaj and A. Shahbazi, in *85th Annual Meeting of ICOLD* (Prague, Czech Republic, 2017).
97. B. A. O. Q. Pham, P. Yu, T. Yang, C. Kuo and H. Tseng, in *Proceeding of 37th IAHR World Congress* (Kuala Lumpur, Malaysia, 2017), pp. 4312–4321.
98. S. Jamshid Mousavi, N. R. Anzab, B. Asl-Rousta and J. H. Kim, *Water Resour. Manag.*, **31**, 3445-3464 (2017).
99. A. F. Berredjem and A. Hani, *J. Water L. Dev.*, **33**, 31-38 (2017).
100. D. Hassan, R. Bano, S. J. Burian and K. Ansari, *Int. J. Sci. Eng. Res.*, **8**, 1745 (2017).

101. M. Romagnoli, M. Portapila, A. Rigalli, G. Maydana, M. Burgués and C. M. García, [Sci. Total Environ.](#), **596–597**, 437-450 (2017).
102. A. Psomas, Y. Panagopoulos, D. Konsta and M. Mimikou, [Procedia Eng.](#), **162**, 269-276 (2016).
103. S. M. Ghoraba, [Alexandria Eng. J.](#), **54**, 583-594 (2015).
104. D. Rajee and P. P. Mujumdar, [Adv. Water Resour.](#), **33**, 312-326 (2010).
105. W. Zhang, P. Liu, H. Wang, X. Lei and M. Feng, [J. Hydro-Environment Res.](#), **16**, 34 (2017).