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Preliminary Studies on Recycling Spent Brine in Green Mango Fermentation

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ABSTRACT

A preliminary study for alleviating pollution from mango processing brine was conducted by recycling spent brines. Spent brines were reclaimed by a sand filtration and an acitvated carbon system. The comparative physico-chemical characteristics of influent and effluent spent brines were investigated. It was found that the values of pH and acidity of effluent brine changed significantly while there was no change in NaCl content. The effluent brine became a visual clear corresponding to a settleable solid, and there were no substantial changes in the total solid without an objectionable odor. Mango brining experiment from defrozen, reclaimed brine and fresh brine were conducted. Pickled mango from reclaimed brine was as good as the pickled mango from fresh brine. The quality of reclaimed brine should be studied during extensive storage at room temperature. A comparison of 4 samples of sweet and sour pickled mango were done and evaluated by a preference test. The overall conclusion from the tasting panel on all samples of sweet and sour pickled mango was that there was not a significant difference in color, odor, flavor, texture or acceptability. Furthermore, the capacity of the reclamation system was also estimated. Results showed that a substantial changes in the chemical composition were significantly different for 15 liters of effluent brine, but for 12 liters of effluent brine, there was only some changes in total solid and dissolved solid. Therefore, further experiment should be performed to large - scale operations for potential recycling brine evaluation.

Key words: pickled mango, reclaimed brine, brine disposal, activated carbon

INTRODUCTION

Mango (*Mangifera Indica* Linn) played an important role on the country's economic development. It was found that the most popular types of preserved mangoes for consumers are sweet and sour pickle mangoes, by intermediate raw mango obtained from green mango fermentation in salted stock brine. The pickle solution is the spent brine from these operations. It was noticed that the spent brine constituted a considerable volume of strong waste with an objectionable odor. The brine disposal problem was compounded by the close proximity of many fruit and vegetable processors to residential areas and by the lack of adequate municipal sewage treatment facilities. Spent brine is a strong pollutant and creates serious disposal problems, because of the large quantities of organic matter and salt contained therein. The organic matter can be removed by biological treatment, but NaCl and other mineral contents are not biodegradable and could pollute the water or soil during land application. Recycling of food processing brine, therefore, could reduce the amount of salt and

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minerals to be discharged as well as conserving water. Several brine recycling systems have been studied. Geisman and Henne (1973), Palnitkar and McFeeters (1975) and McFeeters *et al*. (1977) reported on the recycling of brine in cucumber fermentations. Mercer *et al*. (1970) described a brine recycling and reconditioning system using activated carbon for olive processing. Soderquist (1971) described an activated carbon renovation of spent cherry brine. A filter and activated charcoal system for recycling spent bisulfite brines used in sweet cherry processing was conducted by Panasiuk *et al.*(1977). Whereas Romero *et al*.(2001) described the treatment and recycling of spent brines and osmotic solutions from pickling of olives, cabbage, cucumbers, prunes and cherries. They found that the reclaimed brine may contain polygalacturonase which softens cherries, but thermal inactivation of polygalacturonase could prevent softening. Athanasopoulos (1976) studied the kinetics of thermal inactivation of polygalacturonase in spent brine. However, the recycling of pickling mango's spent brine could not be found in any literature.

This preliminary experiment was confined to the treatment and reuse of brine generated during the production of green mango fermentation. The information developed in this study should be useful for solving potential water pollution problems of salted stock brine factories. It might be the way to alleviate the critical pollution potential of saline liquid wastes discharged from the fermentation process. However, the experiment should be applied to a large scale operation to further evaluate its reuse potential.

MATERIALS AND METHODS

Mango

Fresh green mangoes (Kaew Dhum cultivar) were purchased from the wholesale market. They were washed, and selected for sound and mature fruit prior to pickling.

Spent brine

The spent brine used in the experiment was obtained from a fruit pickling processor in Angthong province from its stock of 12 month old in salted mango brine. It was sampled in 4 brine plastic pails. Each of these pails contained the salted stock brine from the 4 fermentation pails after they were filtered with muslin cloth to remove suspended solids. They were then kept at 10°C in a chill room prior to conducting the experiment.

Brine reclamation system

A laboratory scale brine reclamation system (Panasiuk *et al*., 1977) was assembled for the quantitative measurement of the effluent (schematic diagram on Figure 1). The system consisted of a glass column (36×400 mm), containing 0.45 — 0.60 mm water filtration grade sand, in series with three glass columns, each 33×600 mm, containing activated carbon (CGC 12×40 C, C. Gigaetic Carbon Co. LTD). The total weight of the activated carbon was 456 g. The columns were plugged with glass wool at both ends and were connected by glass tubing attached to rubber stopper joints. Brine was pumped through the system (from the bottom of each column to the top of the succeeding column) with an oil rotary vacuum pump (RP—S50H) at a flow rate of approximately 20 ml / min, controlled by a stopcock at the bottom of the last column.

Each batch of sampled spent brine (influent) was passed through the sand/activated carbon system. The cumulative volume of 15 liters of effluent brine was collected and the samples were taken to be analyzed for the physico-chemical quality, after the completion of each day's operation, The influent brine was also analyzed in the same manner as the effluent brine. All effluent brines were stored at –18°C in a freezing room in order to maintain their stability until green mango could be purchased for pickling.

The green mango brining process

Green mangoes were immersed in reclaimed

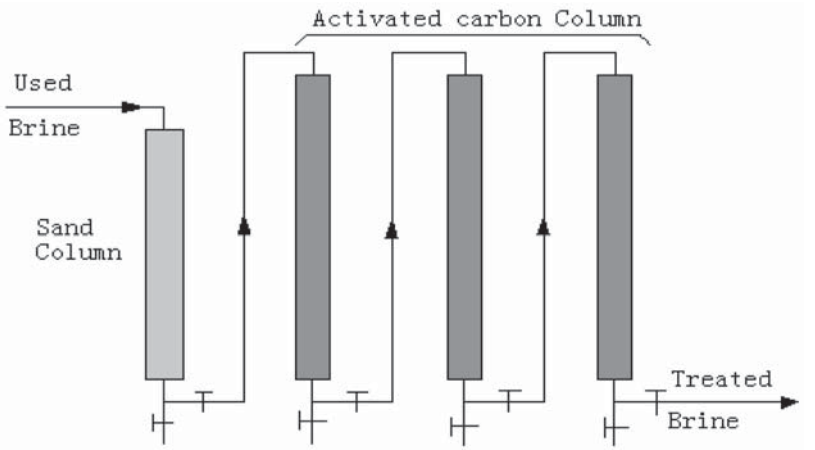

Figure 1 Spent brine treatment system.

brine as a control formulated brine using approximately 1 kg of mango per one liter of brine. The 3 kilograms of fruit was held under the brine with a perforated stainless steel plate fitted to the pail. Three pails of brine were prepared as a control sample that consisted of 10% salt, 0.5% $CaCl_2$ and 0.1% $K_2S_2O_5$. Each pail of reclaimed brine was formulated with the same composition as the control sample by adding NaCl, $CaCl_2$ and $K_2S_2O_5$. During the fermentation period , brine samples were periodically withdrawn for acidity, pH, NaCl determination and microbial analysis. After 40 days, the salted pickled mango stock was considered fully cured and ready for further processing. The remaining brine was taken from each pail for chemical analysis, while the salted pickled mango stock was prepared for sweet and sour pickled mango.

Test methods

Total acidity in the brine was determined by titration with NaOH and expressed as acetic acid. The pH measurement was determined by Orion Model 410A pH meter. Salt content, settleable solids, filterable solids and dissolved solids were determined using a standard method for the examination of water and wastewater(Andrew *et al*., 1995). Calcium was determined using a standard APHA (1998); 3111. Sulfur dioxide was determined using the Optimized Monier-William Method (AOAC, 1995).

Pickled mango process

The following process was used to prepare sweet and sour pickled mango. (1) Wash, peel, pit and cut each fruit into 6 pieces; (2) Refreshen the salted pickled mango stock by soaking it in water for half an hour, in the final washing, 0.5% $CaCl_2$ solution is added to firm the tissue for 1 hour before it is made into sweet and sour pickled mangos; (3) Prepare the syrup by combining 42% sugar, 12% vinegar, 2% salt and 0.15% citric acid; (4) Soak the refreshed pickled mangoes in the syrup for 24 hours at room temperature; (5) Draw off the syrup and reheat; (6) Quickly dip the mango pieces into boiled syrup; (7) Fill in PE bag (flesh: syrup = 1:1) seal and keep in the refrigerator.

Sensory evaluation

Sweet and sour pickled mango products from the reclaimed brine and fresh brine were carried out for organoleptic testing by using the nine point hedonic scale for the subjective evaluation of the product. The panelists were researchers of IFRPD and were asked to evaluate the differences on a nine point scale (1 = extremely dislike, 9 =

extremely like) of flavor, taste, color, texture and acceptability. The experimental design was a Randomized Complete Block Design (RBD) and the data was statistically analyzed using the Analysis of Variance (ANOVA) and Duncan's Multiple Range test with a 95% confidence level.

Investigation of reclamation system capacity

The capacity of the three activated carbon column system was investigated by treating a fixed volume influent. Fifteen liters of effluent was collected and the changes in composition and performance were measured. The experiment was conducted in 5 cycles from the same salted sample stock.

RESULTS AND DISCUSSION

Brine reclamation system

Three influent brine and three effluent brine samples were each analyzed for physico-chemical composition as shown in Table1. The storage spent brine used in the experiment was not significantly different in pH, acidity and NaCl content. A comparison between each batch of the influent brine and effluent brine showed that they contained significant differences in the composition mentioned above with no change in NaCl content. It indicated that NaCl could not be removed by the system. The effluent brine contained less sulfurdioxide and calcium than in the influent brine. The treated brine

Table 1 Physico-chemical characteristic of spent brine from salted mango stock.

Particular	Influent brine			Effluent brine		
	1	2	3	1'	2'	3'
pH ± SD	2.66^{a}±0.06	2.64^{a}±0.01	2.65^{a}±0.03	3.11^{c}±0.01	2.95^{b}±0.01	2.97^{b}±0.01
Ac. ± SD (%)	0.91^{c}±0.01	0.90^{c}±0.03	0.92^{c}±0.01	0.48^{a}±0.01	0.54^{b}±0.01	0.51^{b}±0.00
NaCl±SD (%)	4.76^{d}±0.02	4.68^{ab}±0.04	4.73^{bc}±0.04	4.74^{bc}±0.03	4.61^{a}±0.05	4.70^{bc}±0.05
SO_2 ± SD (ppm)	123.39±1.4	112.2±1.15	125.57±1.5	99.35±3.69	85.51±0.04	91.05±1.24
Ca (mg/l)	997	985	1003	955	970	978
SS ± SD (ml/l)	1.7^{d}±0	1.45^{b}±0.05	1.5^{c}±0	0^{a}±0	0^{a}±0	0^{a}±0
FS ± SD (g/l)	0.66^{b}±0.04	0.83^{b}±0.13	0.94^{c}±0.06	0.08^{a}±0.02	0.22^{a}±0.14	0.15^{a}±0.19
DS ± SD (g/l)	63.95^{a}±0.59	70.23^{c}±0.76	75.81^{d}±0.99	66.07^{ab}±2.84	69.34^{bc}±4.02	70.62^{c}±2.75
TS ± SD (g/l)	75.41^{c}±0.40	79.93^{d}±0.36	80.66^{d}±3.15	68.84^{a}±1.82	70.20^{ab}±0.59	72.22^{b}±0.88

Note: Ac. = acidity as acetic acid; SS = settleable solid; FS = filterable solid; DS = dissolved solid; TS = total solid; SD = standard deviation

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was clear because the total solids were reduced significantly, while the settleable solids became free.

Microorganism examination of the influent brine and the effluent brine revealed the presence of a significant number of microorganisms (Table2). Nevertheless, the effluent brine provided no objectionable odor. All effluent brine samples were kept at –18°C in a freezer in order to retain stability prior to further processing. While Panasiuk *et al*. (1977) reported that the untreated and reclaimed brine were similar in stability during 24 weeks of storage at room temperature.

Green mango brining experiment

Formulated reclaimed brine having the same formular as the fresh brine produced in laboratory was used in the fermentation process. Figure 2 and Figure3 indicated that the initial pH in reclaimed brine was lower but higher in titratable acidity compared to the control brine due to the acid present in the spent brine. Acidity in brine could prevent fruit deterioration from putrefactive and pectolytic organisms at the beginning of fermentation (Desorosier, 1963). The pattern of pH decline and titratable acidity increase occurred during fermentation. Each sample of reclaimed brine and fresh brine showed substantial changes in NaCl (Figure 4).

Table 2 Gross floral in spent brine from green mango fermentation.

Gross floral	Influent brine			Effluent brine		
	1	2	3	1’	2’	3’
TVC (log cfu /ml)	6.04	5.85	6.28	5.48	5.48	6.15
Yeast (log cfu /ml)	6.08	6.18	6.15	5.20	5.08	5.34
Mold (log cfu/ml)	0	0	0	0	0	0
Coliform (MPN/ml)	< 3	< 3	< 3	< 3	< 3	< 3

Note : TVC = Total viable count

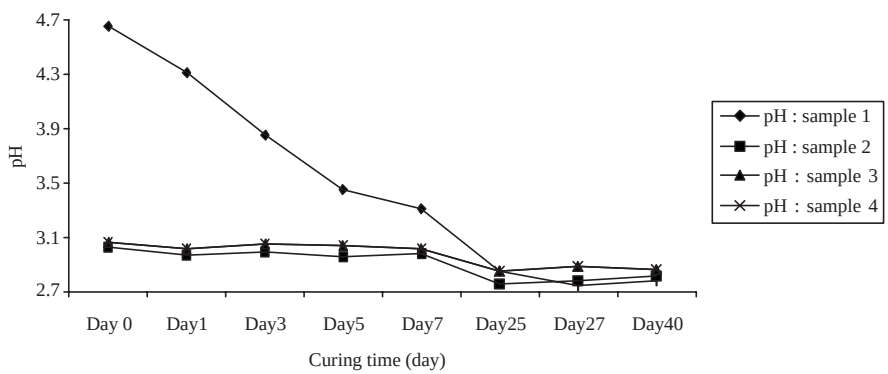

Figure 2 Changes in pH in brine during green mango fermentation.

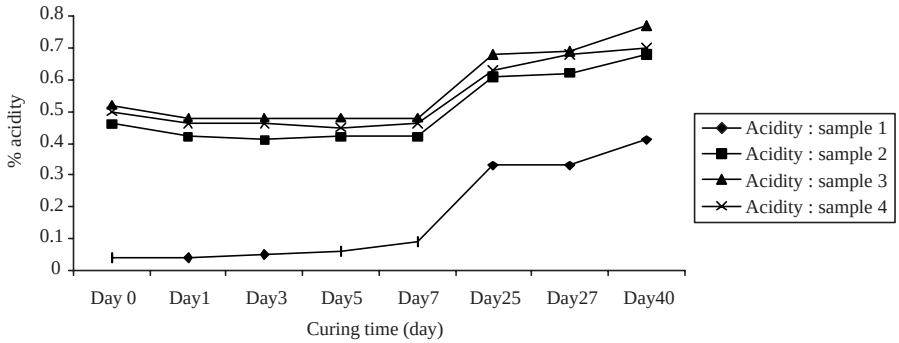

Figure 3 Changes in acidity in brine during green mango fermentation.

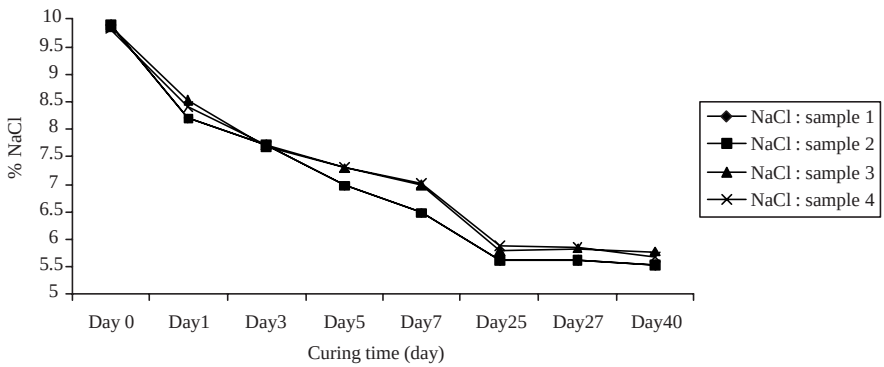

Figure 4 Changes in NaCl content in brine during green mango fermentation.

Pickled mango process and sensory evaluation

All salted mangoes stock appeared to be undergoing a normal fermentation and storage behavior. Salted pickled mango stock is not considered a consumer commodity due to containing high NaCl content (Table 3). Refreshening pickled mango was accomplished by leaching salt from salted mango stock. Sulferdioxide concentration was also minimized during the process with only 24 ppm SO_2 remaining in the final products. Whereas the optimum content of NaCl and total acidity as acetic acid in the products was 1.7% and 0.55%, respectively. It corresponded to the acceptability factor of the panelists (Table 4).

The subjective evaluation data (Table 4) showed no discernible significant differences in color, odor, flavor, texture or acceptability among sweet and sour pickled mangoes from the reclaimed brine and the control. This result showed that the quality of the pickled mango from the individual storage pails was not different.

Investigation of reclamation system capacity

A comparison was made on the investigation of effluent brine for 5 cycles of influent brine from the same sample of stored brine. Substantial changes in the pH value, total acidity and NaCl were significantly different ($p<0.05$). Decreases in the pH of effluent brine and increases in the total acidity were found as influent volume increased in contact time with the activated carbon system. The retention of total acidity in the effluent brine from carbon treatment is desirable since lactic acid is known to be a preservative in the brine of stored olives (Water Pollution Control Research Series, 12060 EHU 03 / 71). However, the activated carbon

became saturated after 4 cycles of influent were treated, because, showed no substantial changes in total solid of effluent brine (Table 5). After 5 cycles treatment, settleable solids (SS) were still not found in the effluent brine due to the sparadic discharge of fine carbon and retained settleable solids.

CONCLUSION

The reclaimed brine from the spent mango processing brine had an average salt content of 4.68%, pH 3.01 and a total acidity as acetic acid 0.51%. It could reduce the waste disposal

Table 3 Composition of salted mango stock and pickled mango products.

Sample number	Salted pickled mango stock		Sweet and sour pickled mango		
	Acid ±SD (%)	NaCl±SD (%)	Acid (%)±SD	NaCl ±SD (%)	SO_2 (ppm)
1	0.68 ± 0.04	4.64 ± 0.005	0.51 ± 0.002	1.73 ± 0.02	24.35
2	0.85 ± 0.09	4.87 ± 0.04	0.55 ± 0.007	1.67 ± 0	24.78
3	0.92 ± 0.005	4.77 ± 0.085	0.55 ± 0.004	1.57 ± 0	24.49
4	0.84 ± 0.045	4.75 ± 0.17	0.53 ± 0.003	1.73 ± 0	24.44

Note: Acid = acidity as acetic acid; solid; SD = standard deviatio

Table 4 Organoleptic evaluation of sweet and sour pickled mango products.

Sample No.	Color	Flavor	Odor	Texture	Acceptability
1	6.89^{a} ± 0.74	7.26^{a} ± 0.81	6.87^{a} ± 0.97	7.30^{a} ± 0.72	6.89^{a} ± 1.23
2	6.89^{a} ± 0.60	7.41^{a} ± 0.77	7.22^{a} ± 0.95	7.24^{a} ± 0.80	7.28^{a} ± 0.91
3	6.98^{a} ± 0.91	7.30^{a} ± 1.02	7.00^{a} ± 1.13	7.11^{a} ± 0.90	6.83^{a} ± 0.98
4	7.33^{a} ± 0.58	7.41^{a} ± 0.65	7.43^{a} ± 0.79	7.48^{a} ± 0.59	7.37^{a} ± 0.77

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1 = Control; 2 — 4 = Treated Sample; SD = Standard Deviation from 23 panelist.

Table 5 Quality of recycling spent brine from capacity evaluation of activated carbon system.

Sample No.	pH ± SD	Ac.(%) ± SD	NaCl(%) ± SD	TS (g/l) ± SD	DS (g/l) ± SD	SS (ml/l) ± SD
Pre-treatment	2.65^{f} ± 0.01	0.96^{f} ± 0.02	5.01^{e} ± 0.00	78.10^{b} ± 0.95	74.10^{d} ± 0.25	1.60 ± .00
1	3.94^{e} ± 0.01	0.15^{a} ± 0.01	4.55^{a} ± 0.01	68.79^{a} ± 0.05	62.71^{a} ± 1.99	0
2	2.90^{d} ± 0.01	0.53^{b} ± 0.00	4.69^{b} ± 0.00	69.13^{a} ± 0.02	68.96^{b} ± 0.14	0
3	2.87^{c} ± 0.01	0.59^{c} ± 0.01	4.78^{c} ± 0.01	70.79^{a} ± 1.67	69.62^{bc} ± 0.52	0
4	2.77^{b} ± 0.01	0.71^{d} ± 0.00	4.80^{c} ± 0.01	75.13^{b} ± 4.24	72.07^{cd} ± 2.56	0
5	2.75^{a} ± 0.01	0.76^{e} ± 0.01	4.92^{d} ± 0.02	77.39^{b} ± 0.32	75.45^{e} ± 1.80	0

The figure on the same column with the same letter are not significantly different ($p > 0.05$).
Ac. = acidity as acetic acid; SS = settleable solid; DS = dissolved solid; TS = total solid;
SD = standard deviation

requirement without adversely affecting product quality. The pickled mango in the reclaimed brine was as good as the pickled mango from the fresh brine. The reclaimed brine should be studied for further processing after long term storage at normal temperature. For the acitivated carbon system capacity in laboratory scale was not still clearly defined in the conclusion. The experiment should be applied to large scale operations and evaluated for reuse potential. Cost analysis is required to establish the economic feasibility of brine reclamation. These analyses must consider the logistics of brining, finishing, disposal cost, storage losses and the unit operations cost for the brine treatment .

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