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RESEARCH ARTICLE

Investigation of wine fermentation from dual mango (*Mangifera indica*) and jackfruit (*Artocarpus heterophyllus*) mash

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Abstract

Jackfruit and mango fruit have a distinctive aromatic flavour and a delicious taste with numerous bioactive components useful for human health. They are highly perishable at ambient conditions after harvesting. It was essential to convert these good food supplies into value-added products like wine. The main objective of this study was to verify the effectiveness of material replacement ratios (6 %-18 %) of jackfruit to mango mash, initial pH (4.0-4.8), initial total dry matter (16-32 °Bx), yeast *Saccharomyces cerevisiae* inoculation ratios (0.8-1.6 g/L) to wine quality basing on the alcoholic content (%), acidity (%), total dry matter (%) and overall acceptance (sensory score). The wine fermentation process was performed in 10 days. Results showed that the best wine quality would be obtained with alcoholic content (1.891 ± 0.002 %), acidity (1.446 ± 0.001 %), total dry matter (0.363 ± 0.003 %) and overall acceptance (8.60 ± 0.01 sensory score) by the jackfruit/mango incorporation of 12 %, initial pH 4.4, initial total dry matter 24 °Bx, yeast ratio 1.4 g/L. Jackfruit incorporated with mango created a pleasant flavour wine. Mango blended with jackfruit for wine making could be considered an intelligent strategy to exploit and alter the abundant source into a valuable product. This research opened a wide opportunity to diversify fruit wine from different valuable crops.

Keywords: jackfruit; mango; replacement; wine; yeast

Introduction

Mango (*Mangifera indica*) has a pleasant taste with abundant nutritional components like amino acids, beta-carotene and ascorbic acid, with low cholesterol (1). Jackfruit (*Artocarpus heterophyllus*) contains a good source of minerals, dietary fibre, vitamin C and beta-carotene, showing an excellent antioxidant potential (2). However, they were not stable under a hot and humid environment in tropical regions. Wine making from these fruits could diversify wine varieties and minimise post-harvest damage of these valuable crops. Several notable studies mentioned the processing of mango or jackfruit wine. Jackfruit has been blended with tropical fruits. Apple-mango wine was prepared from the fermentation of mango juice with 0.05 % yeast at 25 °C (3). Different mango varieties were examined to manufacture fruit wine (4). Mango must at pH 5.0 was treated with 100 ppm of SO_2 and then incubated at 25 °C to obtain high wine quality (5). Mango wine manufactured from a yeast-mango peel immobilised biocatalyst system was studied (6). One observation of modifications in the chemical attributes of mango wine was carried out (7). Jackfruit wine was prepared from the fermentation of jackfruit juice at 30 °C for 14 days with 2 % *Saccharomyces cerevisiae* (8). Jackfruit wine containing high ethanol content (18 %) with pleasant organoleptic attributes was manufactured from the jackfruit bulb (9). Jackfruit juice was mixed with pineapple, amla and aloe vera to produce jackfruit wine (10). One experiment was arranged to demonstrate the possibility of wine fermentation from jackfruit blended with kokum (11). There was no report mentioning the incorporation of mango and jackfruit pulp for wine making. The purpose of this study was to demonstrate the possibility of wine fermentation prepared from these valuable sources. The effect of various technical parameters, such as partial replacement ratios of jackfruit to mango mash, initial pH, initial dry matter and yeast inoculation ratio in wine fermentation was thoroughly investigated. Utilisation of jackfruit and mango fruit for wine fermentation contributed to the diversification of crop products to improve their added value in the food chain.

Materials and Methods

Materials

Jackfruit and mango fruits were cultivated in gardens in Soc Trang city, Soc Trang province, Vietnam. Overall cultivation process strictly followed VietGap standards by controlling pesticide and chemical application to obtain an acceptable residue. They were carefully harvested at technical maturity to minimise post-harvest loss. Fine sugar was purchased from the local market. *Saccharomyces cerevisiae* yeast (2×10^9 CFU/g) was obtained from Novaco Pharmaceuticals. Pectinase was purchased from

Novozymes (Denmark). Chemical reagents such as sodium hydroxide (VMC Group), hydrochloric acid (from Vietchem Co. Ltd), citric acid (from VMC Group), 3,5-dinitrosalicylic acid (from SBC Scientific Co. Ltd), sodium carbonate (from Vietchem Co. Ltd) and phenolphthalein (from VMC Group) were all analytical grade.

Researching method

Ripe mango and jackfruit were manually sorted and graded one by one to ensure the appropriate quality for wine fermentation. They were peeled by hand, cut by knife to collect pulp. Pulp was then thoroughly washed and left to drain, ground into mash, treated with 0.05 % pectinase for 90 minutes at ambient conditions and ready for experiments. Jackfruit mash was incorporated with mango mash in different ratios (6 %, 9 %, 12 %, 15 % and 18 %), adjusted pH (4.0, 4.2, 4.4, 4.6 and 4.8) by pH meter using citric acid 99.5 % and sodium carbonate 99.2 %, prepared initial total dry matter (16, 20, 24, 28 and 32 °Bx) by adding fine sugar with the support of hand-held refractometer, inoculated yeast (0.8, 1.0, 1.2, 1.4 and 1.6 g/L) by *Saccharomyces cerevisiae* yeast ($2x10^9$ CFU/g). The fermentation process lasted for 10 days in ambient temperature (28 °C) without agitation in Erlenmeyer flasks (volume 250 mL) with a two-day sampling interval. Flasks were tightly sealed with a penicillin septum. Bubbling pure sterile argon was flushed through a needle into the fermentation medium for 10 min to create anaerobic conditions. The fermented medium was filtered through muslin cloth and the filtrate was kept in sterilised glass bottles.

Quality sampling tests of the mango-jackfruit wine were performed on alcoholic content (%), acidity (%), total dry matter (%) and overall acceptance (sensory score). Alcoholic content (%) was determined by distillation and alcolyzer module 3001 Wine using an Anton Paar instrument. Acidity (%) was measured by titration with NaOH 0.1 N and phenolphthalein 1 %. Total dry matter (%) was verified by the Krivorotova and Sereikaite protocol, implementing 3,5-dinitrosalicylic acid 98 % with three replications (12). Overall acceptance (sensory score) was evaluated on flavour, colour and taste using 9 point-Hedonic scale (from minor 1 = dislike greatly to major 9 = like). A group of panellists consisted of 15 members aged 26-34 years old participated in the evaluation. The organoleptic evaluation was randomised on samples branded with incidentally two-digit codes.

Statistical analysis

All experiments were performed in three replications. The results data were expressed as average ± standard deviation. Statistical analysis was handled by the Statgraphics software using Centurion version XVI.I. The average number and standard deviation were achieved by analysis of random patterns forecasting the group statistics. 95 % of the data would be presented to coincide within the range we presented, the lower and upper limits of this extent representing 95 % reliable bounds of outcomes.

Results and Discussion

Influence of the replacement ratio of jackfruit to mango mash on wine quality

The fermentation batch was prepared by various ratios of jackfruit to mango mash (6 %, 9 %, 12 %, 15 % and 18 %) with the fixed parameters of the initial soluble solids (16 °Bx), pH (4.0) and yeast ratio (0.8 g/L). This fermentation occurred at room temperature for 10 days. In a two-day interval, samples were taken to analyse the alcoholic content. Incorporation of jackfruit to mango mash at 15 % had a significant impact on the alcoholic content of wine (Table 1). Alcoholic content in wine showed a minor accumulation with 18 % jackfruit supplementation. It's noticeable that the alcohol content in wine increased with fermentation time. Jackfruit should be incorporated 15 % into the mango mash to prepare for the wine fermentation to obtain a high alcoholic content (1.068 ± 0.002 %). Research indicates that 15 % banana incorporated into 85 % pineapple produced wine containing the highest alcoholic content (13). High alcohol content (12 %) was obtained by mixing 15 % amla juice into jackfruit juice in wine fermentation (10).

Increasing jackfruit to mango mash ratios (6 %, 9 %, 12 %, 15 % and 18 %) created an accumulation of acidity in wine. At 15 % jackfruit supplementation into mango mash, acidity in wine accumulated at 0.632 ± 0.001% after 10 days of fermentation (Table 2). There was no significant difference in acidity in wine between 15 % and 18 % jackfruit incorporation. Jackfruit supplementation provided more substrate for yeast cells to consume and produce high acid content. The result of this experiment was similar to findings in other reports (14, 15). The highest acidity (0.052 %) was noticed in jackfruit-amla wine prepared from 15 % amla juice with 85 % jackfruit juice (10). The more jackfruit is incorporated into the

Table 1. Effectiveness of the jackfruit/mango ratio to alcoholic content in wine

Fermentation time (days)	Jackfruit/mango ratio (%)				
	6	9	12	15	18
2	0.204 ± 0.002^b	0.257 ± 0.003^{ab}	0.349 ± 0.002^{ab}	0.504 ± 0.001^a	0.517 ± 0.000^a
4	0.249 ± 0.000^b	0.340 ± 0.001^{ab}	4.15 ± 0.000^{ab}	0.593 ± 0.003^a	0.660 ± 0.003^a
6	0.358 ± 0.003^b	0514 ± 0.000^{ab}	6.07 ± 0.002^{ab}	0.745 ± 0.000^a	0.805 ± 0.001^a
8	0.495 ± 0.004^b	0.681 ± 0.003^{ab}	7.92 ± 0.004^{ab}	0.953 ± 0.001^a	1.039 ± 0.002^a
10	0.517 ± 0.002^b	0.706 ± 0.001^{ab}	9.25 ± 0.001^{ab}	1.068 ± 0.002^a	1.102 ± 0.000^a

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 2. Effectiveness of the jackfruit/mango ratio to acidity in wine

Fermentation time (days)	Jackfruit/mango ratio (%)				
	6	9	12	15	18
2	0.309 ± 0.003^b	0.347 ± 0.000^{ab}	0.385 ± 0.001^{ab}	0.496 ± 0.002^a	0.514 ± 0.002^a
4	0.328 ± 0.001^b	0.365 ± 0.002^{ab}	0.409 ± 0.000^{ab}	0.510 ± 0.001^a	0.523 ± 0.000^a
6	0.374 ± 0.000^b	0.401 ± 0.003^{ab}	0.462 ± 0.004^{ab}	0.567 ± 0.003^a	0.594 ± 0.001^a
8	0.409 ± 0.002^b	0.471 ± 0.001^{ab}	0.490 ± 0.002^{ab}	0.601 ± 0.000^a	0.640 ± 0.003^a
10	0.435 ± 0.001^b	0.484 ± 0.000^{ab}	0.515 ± 0.003^{ab}	0.632 ± 0.001^a	0.658 ± 0.002^a

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 3. Effectiveness of jackfruit/mango ratio to total dry matter in wine

Fermentation time (days)	Jackfruit/mango ratio (%)				
	6	9	12	15	18
2	1.208 ± 0.000^{b}	1.285 ± 0.002^{ab}	1.340 ± 0.000^{ab}	1.429 ± 0.000^{a}	1.473 ± 0.003^{a}
4	1.140 ± 0.002^{b}	1.209 ± 0.001^{ab}	1.279 ± 0.003^{ab}	1.402 ± 0.003^{a}	1.425 ± 0.001^{a}
6	0.929 ± 0.001^{b}	1.133 ± 0.000^{ab}	1.184 ± 0.004^{ab}	1.254 ± 0.002^{a}	1.272 ± 0.002^{a}
8	0.735 ± 0.003^{b}	0.886 ± 0.000^{ab}	0.965 ± 0.001^{ab}	1.019 ± 0.000^{a}	1.046 ± 0.000^{a}
10	0.606 ± 0.004^{b}	0.725 ± 0.003^{ab}	0.787 ± 0.002^{ab}	0.836 ± 0.004^{a}	0.877 ± 0.003^{a}

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

mango mash, the higher the total dry matter remains in the wine. There was no significant difference in total dry matter in wine by 15 % and 18 % jackfruit. There was a descending trend of total dry matter with the fermentation time. After 10 days of fermentation at 15 % jackfruit supplementation, total dry matter remained in wine at 0.836 ± 0.004 % (Table 3). Jackfruit bulb contained high initial soluble solids (18.8 %-26.0 %) compared to mango pulp (10.1 %) (16, 17). Hence, it contributed to the high total dry matter in wine. Fruit wine prepared from the fermentation of 15 % amla juice with 85 % jackfruit juice had the highest total soluble solids (6.25 %) (10).

Increasing jackfruit supplementation to mango mash from 6 % to 15 % created better overall acceptance of wine. There was no significant difference in the overall acceptance of wine between 15 % and 18 % jackfruit replacement. After 10 days of fermentation, the wine achieved a high sensory score (5.97 ± 0.02) with 15 % jackfruit incorporation (Table 4). These results were in accordance with the following findings. Jackfruit wine had an improvement of organoleptic properties by adding 15 % amla juice into the jackfruit juice during fermentation (10). In another report, 85 % jackfruit pulp + 15 % kokum juice was optimal for making the best quality wine (11).

Effectiveness of pH in a fermentation batch on wine quality

pH played an important role in wine fermentation, as it facilitated or hindered yeast growth. pH in the fermentation batch was varied from 4.0 to 4.8 by the same jackfruit to mango ratio (15 %), the initial solids (16 °Bx) and yeast ratio (0.8 %). The fermentation processed at ambient temperature for 10 days. In a two-day interval, samples were periodically taken to measure the ethanol content. pH induced a significant impact on alcoholic content (Table 5). Results clearly showed that pH 4.4 created favourable conditions for yeast growth to produce more ethanol (1.405 ± 0.004 %). pH in the fermentation batch revealed a great influence on acidity in wine (Table 6). An optimal initial pH of 4.4 was noticed for yeast growth to accumulate the highest acidity (1.138 ± 0.002 %). Total dry matter remaining in wine was noticed at the lowest level, 0.669 ± 0.001 % by the initial pH 4.4 in the fermentation batch (Table 7). It's easily explained due to the suitable pH producing the favourable condition for yeast growth to consume much more soluble solid content. The highest sensory score of wine was recorded at 8.19 ± 0.02 by the initial pH 4.4 (Table 8). There was also an increasing

Table 4. Effectiveness of jackfruit/mango ratio to overall acceptance (sensory score) of wine

Fermentation time (days)	Jackfruit/mango ratio (%)				
	6	9	12	15	18
2	2.19 ± 0.01^{b}	2.87 ± 0.04^{ab}	3.39 ± 0.01^{ab}	3.95 ± 0.03^{a}	4.01 ± 0.00^{a}
4	2.48 ± 0.04^{b}	3.12 ± 0.00^{ab}	3.92 ± 0.02^{ab}	4.73 ± 0.01^{a}	4.80 ± 0.04^{a}
6	2.79 ± 0.03^{b}	3.68 ± 0.03^{ab}	4.75 ± 0.00^{ab}	5.60 ± 0.00^{a}	5.73 ± 0.00^{a}
8	3.16 ± 0.01^{b}	4.25 ± 0.02^{ab}	5.19 ± 0.03^{ab}	5.83 ± 0.04^{a}	6.00 ± 0.03^{a}
10	3.25 ± 0.02^{b}	4.48 ± 0.01^{ab}	5.30 ± 0.01^{ab}	5.97 ± 0.02^{a}	6.07 ± 0.02^{a}

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 5. Effectiveness of pH in fermentation batch on alcoholic content in wine

Fermentation time (days)	Ph				
	4.0	4.2	4.4	4.6	4.8
2	0.504 ± 0.001^{bc}	0.542 ± 0.001^{b}	0.685 ± 0.000^{a}	0.571 ± 0.002^{ab}	0.471 ± 0.003^{c}
4	0.593 ± 0.003^{bc}	0.670 ± 0.003^{b}	0.804 ± 0.002^{a}	0.743 ± 0.001^{ab}	0.507 ± 0.000^{c}
6	0.745 ± 0.000^{bc}	0.893 ± 0.002^{b}	0.979 ± 0.003^{a}	0.911 ± 0.003^{ab}	0.712 ± 0.002^{c}
8	0.953 ± 0.001^{bc}	1.142 ± 0.000^{b}	1.338 ± 0.001^{a}	1.264 ± 0.000^{ab}	0.856 ± 0.001^{c}
10	1.068 ± 0.002^{bc}	1.230 ± 0.003^{b}	1.405 ± 0.004^{a}	1.378 ± 0.004^{ab}	0.981 ± 0.003^{c}

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 6. Effectiveness of initial pH in fermentation batch to acidity in wine

Fermentation time (days)	pH				
	4.0	4.2	4.4	4.6	4.8
2	0.496 ± 0.002^{bc}	0.549 ± 0.003^{b}	0.625 ± 0.002^{a}	0.590 ± 0.000^{ab}	0.417 ± 0.003^{c}
4	0.510 ± 0.001^{bc}	0.590 ± 0.000^{b}	0.732 ± 0.003^{a}	0.661 ± 0.003^{ab}	0.472 ± 0.001^{c}
6	0.567 ± 0.003^{bc}	0.658 ± 0.002^{b}	0.874 ± 0.001^{a}	0.715 ± 0.002^{ab}	0.490 ± 0.002^{c}
8	0.601 ± 0.000^{bc}	0.792 ± 0.004^{b}	1.002 ± 0.000^{a}	0.917 ± 0.004^{ab}	0.548 ± 0.000^{c}
10	0.632 ± 0.001^{bc}	0.815 ± 0.003^{b}	1.138 ± 0.002^{a}	1.036 ± 0.000^{ab}	0.603 ± 0.004^{c}

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 7. Effectiveness of initial pH in fermentation batch to total dry matter in wine

Fermentation time (days)	pH				
	4.0	4.2	4.4	4.6	4.8
2	1.429 ± 0.000^{ab}	1.315 ± 0.001^{b}	1.149 ± 0.002^{c}	1.250 ± 0.003^{bc}	1.442 ± 0.000^{a}
4	1.402 ± 0.003^{ab}	1.276 ± 0.000^{b}	1.060 ± 0.000^{c}	1.179 ± 0.004^{bc}	1.411 ± 0.003^{a}
6	1.254 ± 0.002^{ab}	1.204 ± 0.003^{b}	0.914 ± 0.001^{c}	1.065 ± 0.000^{bc}	1.348 ± 0.001^{a}
8	1.019 ± 0.000^{ab}	0.965 ± 0.001^{b}	0.780 ± 0.003^{c}	0.878 ± 0.002^{bc}	1.209 ± 0.003^{a}
10	0.836 ± 0.004^{ab}	0.807 ± 0.002^{b}	0.669 ± 0.001^{c}	0.729 ± 0.001^{bc}	0.947 ± 0.002^{a}

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 8. Effectiveness of initial pH in fermentation batch to overall acceptance (sensory score) of wine

Fermentation time (days)	pH				
	4.0	4.2	4.4	4.6	4.8
2	3.95 ± 0.03^{bc}	4.69 ± 0.02^{b}	5.71 ± 0.04^{a}	5.01 ± 0.02^{ab}	3.42 ± 0.02^{c}
4	4.73 ± 0.01^{bc}	5.10 ± 0.03^{b}	6.29 ± 0.01^{a}	5.95 ± 0.03^{ab}	4.17 ± 0.03^{c}
6	5.60 ± 0.00^{bc}	6.43 ± 0.00^{b}	7.01 ± 0.03^{a}	6.80 ± 0.04^{ab}	5.13 ± 0.01^{c}
8	5.83 ± 0.04^{bc}	6.97 ± 0.01^{b}	8.04 ± 0.00^{a}	7.45 ± 0.00^{ab}	5.27 ± 0.00^{c}
10	5.97 ± 0.02^{bc}	7.10 ± 0.03^{b}	8.19 ± 0.02^{a}	7.75 ± 0.01^{ab}	5.41 ± 0.04^{c}

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

trend in the sensory score with the fermentation time. This could be explained by the strong proliferation of yeast at the suitable pH condition. Mango wine was produced by fermentation at an initial pH of 5.0 to achieve good wine quality (5). An increment of total acidity was found in wine making prepared from blended fruits like pawpaw, banana and watermelon (18). pH and acidity directly affect the overall acceptance of wine by transferring acidic taste to the final commodity (18).

Effectiveness of initial solid content in fermentation batch on wine quality

Initial total dry matter played an important role in yeast proliferation, contributing to wine quality indicators. Fine sugar was added to the fermentation batch prepared from 15 % jackfruit and 85 % of mango mash at different dry matter contents (16, 20, 24, 28 and 32 °Bx). The fermentation process occurred at pH 4.4 with 0.8 % yeast inoculation, lasting for 10 days. The highest ethanol content in wine was noticed at 24 °Bx of the initial dry matter (Table 9). The initial dry matter in the fermentation batch had a great impact on the acidity of the wine. There was a significant difference in acidity among initial dry matter groups (Table 10). Acidity in wine accumulated at 1.540 ± 0.001 g/L by the end of fermentation duration. Initial dry matter had a great influence on total dry matter in wine (Table 11). An adequate total dry matter in wine directly affects a pleasant organoleptic attribute. Total dry matter remained at the lowest level (0.511 ± 0.000 %) by the initial dry matter (24 °Bx) in the fermentation batch. The sensory score of the wine was affected by the initial dry matter in the fermentation batch. Too low or too high initial dry matter induced a backward condition for yeast accumulation (19). The highest overall acceptance of wine was recorded at 8.59 ± 0.03 by 24 °Bx of the initial dry matter in the fermentation batch (Table 12). It's easily noticed that at 28 and 32 °Bx, yeast encountered backward condition to grow due to high osmotic pressure generated from high soluble solid content. In this research, the fermentation batch should be prepared at 24 °Bx in maximum for yeast to consume and release the best wine quality.

Yeast released pyruvic decarboxylase and alcohol dehydrogenase enzymes to convert carbohydrates to alcohol. The increase in ethanol content in mango wine was consistent with the high initial total soluble solids in mango juice (7). High initial dry matter (over 14 %) inhibited yeast cell proliferation in jackfruit wine fermentation (8). Ethanol content accumulated with an increase in the initial total soluble solid content while making mango wine (7). There was a decreasing trend of total dry matter in wine during the

Table 9. Effectiveness of the initial dry matter in fermentation batch to alcoholic content in wine

Fermentation time (days)	Initial dry matter (°Bx)				
	16	20	24	28	32
2	0.685 ± 0.000^{bc}	0.712 ± 0.004^{b}	0.845 ± 0.001^{a}	0.801 ± 0.001^{ab}	0.603 ± 0.000^{c}
4	0.804 ± 0.002^{bc}	0.885 ± 0.000^{b}	0.992 ± 0.004^{a}	0.920 ± 0.003^{ab}	0.736 ± 0.003^{c}
6	0.979 ± 0.003^{bc}	1.079 ± 0.003^{b}	1.148 ± 0.002^{a}	1.105 ± 0.001^{ab}	0.886 ± 0.004^{c}
8	1.338 ± 0.001^{bc}	1.475 ± 0.001^{b}	1.629 ± 0.003^{a}	1.547 ± 0.004^{ab}	1.124 ± 0.002^{c}
10	1.405 ± 0.004^{bc}	1.583 ± 0.004^{b}	1.740 ± 0.002^{a}	1.645 ± 0.001^{ab}	1.288 ± 0.000^{c}

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 10. Effectiveness of initial dry matter in fermentation batch to acidity in wine

Fermentation time (days)	Initial dry matter (°Bx)				
	16	20	24	28	32
2	0.625 ± 0.002^{bc}	0.669 ± 0.004^{b}	0.710 ± 0.001^{a}	0.692 ± 0.002^{ab}	00.604 ± 0.002^{c}
4	0.732 ± 0.003^{bc}	0.793 ± 0.001^{b}	0.876 ± 0.003^{a}	0.820 ± 0.000^{ab}	0.701 ± 0.000^{c}
6	0.874 ± 0.001^{bc}	0.947 ± 0.003^{b}	1.118 ± 0.002^{a}	1.054 ± 0.003^{ab}	0.798 ± 0.03^{c}
8	1.002 ± 0.000^{bc}	1.106 ± 0.002^{b}	1.332 ± 0.004^{a}	1.209 ± 0.001^{ab}	0.935 ± 0.001^{c}
10	1.138 ± 0.002^{bc}	1.328 ± 0.000^{b}	1.540 ± 0.001^{a}	1.442 ± 0.004^{ab}	1.083 ± 0.002^{c}

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 11. Effectiveness of initial dry matter in fermentation batch to total dry matter in wine

Fermentation time (days)	Initial dry matter (°Bx)				
	16	20	24	28	32
2	1.149 ± 0.002[ab]	1.105 ± 0.004[b]	1.003 ± 0.001[c]	1.041 ± 0.000[bc]	1.168 ± 0.004[a]
4	1.060 ± 0.000[ab]	1.014 ± 0.002[b]	0.915 ± 0.003[c]	0.987 ± 0.003[bc]	1.096 ± 0.000[a]
6	0.914 ± 0.001[ab]	0.886 ± 0.001[b]	0.778 ± 0.002[c]	0.820 ± 0.001[bc]	0.975 ± 0.003[a]
8	0.780 ± 0.003[ab]	0.713 ± 0.003[b]	0.600 ± 0.004[c]	0.642 ± 0.003[bc]	0.811 ± 0.001[a]
10	0.669 ± 0.001[ab]	0.604 ± 0.000[b]	0.511 ± 0.000[c]	0.580 ± 0.002[bc]	0.697 ± 0.000[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 12. Effectiveness of initial dry matter (°Bx) in fermentation batch to overall acceptance (sensory score) of wine

Fermentation time (days)	Initial dry matter (°Bx)				
	16	20	24	28	32
2	5.71 ± 0.04[bc]	5.87 ± 0.00[b]	6.30 ± 0.00[a]	6.06 ± 0.01[ab]	5.04 ± 0.03[c]
4	6.29 ± 0.01[bc]	6.59 ± 0.04[b]	6.99 ± 0.02[a]	6.87 ± 0.00[ab]	5.87 ± 0.02[c]
6	7.01 ± 0.03[bc]	7.26 ± 0.02[b]	7.57 ± 0.00[a]	7.42 ± 0.02[ab]	6.35 ± 0.00[c]
8	8.04 ± 0.00[bc]	8.19 ± 0.03[b]	8.51 ± 0.01[a]	8.35 ± 0.04[ab]	7.47 ± 0.04[c]
10	8.19 ± 0.02[bc]	8.33 ± 0.01[b]	8.59 ± 0.03[a]	8.48 ± 0.03[ab]	7.84 ± 0.01[c]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

fermentation duration. This may be due to the conversion of carbohydrate into ethanol or participation of the Maillard reaction leading to non-enzymatic discolouration due to interaction of reducing sugar and amino acid (7). Wine making was proven to form different secondary substances such as alcohols, esters, carbonyls, organic acids acetyls that influenced the sensory behaviour of the final commodity and related to fantastic taste (20).

Effectiveness of the initial yeast ratio in the fermentation batch on wine quality

Saccharomyces cerevisiae yeast (2×10^9 CFU/g) was inoculated into a fermentation batch in different ratios (0.8, 1.0, 1.2, 1.4 and 1.6 g/L). Results showed that the more yeast added into the fermentation batch, the higher the ethanol content in wine (Table 13). However, there was no significant difference in ethanol content between 1.4 and 1.6 g/L of yeast inoculation. Therefore, it's necessary to save the production by choosing 1.4 g/L of yeast for fermentation. Yeast inoculation ratios contributed to an insignificant difference in acidity in wine (Table 14). Total dry matter was an important index to reveal the efficiency of fermentation. The more yeast added into the fermentation batch, the lower the dry matter in the wine was recorded (Table 15). The yeast inoculation ratio contributed a minor impact to the overall acceptance of wine (Table 16). The fermentation process should be prepared from 1.4 g/L of

Table 13. Effectiveness of the yeast inoculation in the fermentation batch on the alcoholic content in the wine

Fermentation time (days)	Yeast ratio (g/L)				
	0.8	1.0	1.2	1.4	1.6
2	0.845 ± 0.001[c]	0.858 ± 0.001[bc]	0.885 ± 0.003[b]	0.911 ± 0.002[ab]	0.915 ± 0.001[a]
4	0.992 ± 0.004[c]	1.008 ± 0.003[bc]	1.043 ± 0.000[b]	1.089 ± 0.001[ab]	1.093 ± 0.002[a]
6	1.148 ± 0.002[c]	1.167 ± 0.002[bc]	1.190 ± 0.003[b]	1.254 ± 0.000[ab]	1.261 ± 0.003[a]
8	1.629 ± 0.003[c]	1.690 ± 0.000[bc]	1.775 ± 0.001[b]	1.826 ± 0.003[ab]	1.835 ± 0.001[a]
10	1.740 ± 0.002[c]	1.773 ± 0.001[bc]	1.842 ± 0.001[b]	1.891 ± 0.002[ab]	1.900 ± 0.002[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 14. Effectiveness of yeast inoculation in fermentation batch to acidity in wine

Fermentation time (days)	Yeast ratio (g/L)				
	0.8	1.0	1.2	1.4	1.6
2	0.710 ± 0.001[a]	0.713 ± 0.003[a]	0.715 ± 0.000[a]	0.716 ± 0.000[a]	0.716 ± 0.000[a]
4	0.876 ± 0.003[a]	0.877 ± 0.000[a]	0.880 ± 0.001[a]	0.880 ± 0.001[a]	0.881 ± 0.003[a]
6	1.118 ± 0.002[a]	1.120 ± 0.001[a]	1.120 ± 0.000[a]	1.120 ± 0.002[a]	1.121 ± 0.001[a]
8	1.332 ± 0.004[a]	1.334 ± 0.002[a]	1.334 ± 0.003[a]	1.335 ± 0.003[a]	1.337 ± 0.002[a]
10	1.540 ± 0.001[a]	1.540 ± 0.003[a]	1.543 ± 0.002[a]	1.446 ± 0.001[a]	1.547 ± 0.000[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 15. Effectiveness of yeast ratio in fermentation batch to total dry matter in wine

Fermentation time (days)	Yeast ratio (g/L)				
	0.8	1.0	1.2	1.4	1.6
2	1.003 ± 0.001[a]	0.945 ± 0.002[ab]	0.903 ± 0.003[b]	0.862 ± 0.000[bc]	0.804 ± 0.001[c]
4	0.915 ± 0.003[a]	0.864 ± 0.001[ab]	0.813 ± 0.000[b]	0.775 ± 0.001[bc]	0.711 ± 0.003[c]
6	0.778 ± 0.002[a]	0.705 ± 0.003[ab]	0.649 ± 0.001[b]	0.597 ± 0.002[bc]	0.535 ± 0.002[c]
8	0.600 ± 0.004[a]	0.551 ± 0.000[ab]	0.502 ± 0.001[b]	0.449 ± 0.000[bc]	0.400 ± 0.000[c]
10	0.511 ± 0.000[a]	0.485 ± 0.002[ab]	0.427 ± 0.003[b]	0.363 ± 0.003[bc]	0.314 ± 0.003[c]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Table 16. Effectiveness of yeast ratio in fermentation batch to overall acceptance (sensory score) of wine

Fermentation time (days)	Yeast ratio (g/L)				
	0.8	1.0	1.2	1.4	1.6
2	6.30 ± 0.00[a]	6.30 ± 0.03[a]	6.33 ± 0.02[a]	6.33 ± 0.01[a]	6.34 ± 0.02[a]
4	6.99 ± 0.02[a]	6.99 ± 0.03[a]	7.01 ± 0.00[a]	7.00 ± 0.03[a]	7.02 ± 0.01[a]
6	7.57 ± 0.00[a]	7.56 ± 0.00[a]	7.58 ± 0.01[a]	7.56 ± 0.02[a]	7.59 ± 0.03[a]
8	8.51 ± 0.01[a]	8.53 ± 0.01[a]	8.52 ± 0.03[a]	8.55 ± 0.00[a]	8.54 ± 0.00[a]
10	8.59 ± 0.03[a]	8.57 ± 0.02[a]	8.57 ± 0.00[a]	8.60 ± 0.01[a]	8.62 ± 0.03[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not significantly different (α = P=0.05).

Saccharomyces cerevisiae yeast (2 × 10^9 CFU/g) to achieve an acceptable value of organoleptic attributes. In wine making, the efficiency of fermentation relied on the capability and metabolism of yeast to metabolize available substrates to ethanol and secondary elements (20). Yeast inoculation at 0.05 % was adequate to produce mango wine (3). Yeast ratio should not be over 2.0 % to facilitate yeast growth and metabolism during jackfruit wine making (8).

Conclusion

Jackfruit and mango were available during the harvesting season. They contained numerous nutritional contents beneficial for human health. This research successfully investigated the possibility of mixing jackfruit and mango pulp for wine fermentation. Several parameters affecting wine quality, like jackfruit/mango ratio, initial pH, initial soluble solid content and yeast inoculation ratio in the fermentation batch, were demonstrated. Jackfruit blended mango wine was a shelf-stable value-added commodity prepared from the fermentation of ripe mango and jackfruit mash. Deep processing of these fruits into value-added wine could improve their economic value in the food supply.

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Authors' contributions

NPM conducted the experiments and prepared the manuscript. The author read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: The author strongly confirms that this research was conducted with no conflict of interest.

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