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BANANA PSEUDO STEM CORE, A NOVEL SUBSTRATE: TURNING WASTE INTO ALCOHOLIC AND PROBIOTIC BEVERAGES

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ABSTRACT

In the present investigation, nutritious and sugar- rich Banana pseudo stem core (BPS) served as a novel substrate for developing fermented beverages involving reference microorganisms, *Saccharomyces ellipsoideus* (RY4) and *Lactobacillus acidophilus* (RLAB4) along with other indigenous isolates of yeasts and lactic acid bacteria. The results indicated that the performance of the reference organisms was significantly better, as compared to BPS isolates. It was observed that beverage using RY4 produced highest alcohol content of 7.03% after 6 days. Further, a desirable microbial population for probiotic beverages was attained in RLAB4 (4.5 x 10^6 cfu ml^{-1} beverage). Additionally, treatment with RLAB4 also exhibited highest vitamin C (0.38 mg 100 ml^{-1}). Sensory evaluation disclosed that the beverages developed using the reference strains had better acceptability than their indigenous counterparts. The study also paves way for efficient utilization of voluminous biomass for the production of both alcoholic and non- alcoholic probiotic drinks, helping in valorization of the agro-residue.

Keywords: Agro-residue, Banana pseudo stem core, Bioprocess, Fermented beverages, Waste valorization

With several varieties being consumed worldwide, Banana has a total production of 124 million tonnes annually. Globally, India ranks first in the list of leading Banana producing countries, followed by China, Indonesia, Brazil etc., with an average production of 33 million tonnes (FAOSTAT, 2021). However, apart from fruit, this crop also yields huge quantity of wastes in the form of pseudo stem that accounts to about 220 tonnes/ ha annually (Ahmed and Danish, 2018). Attempts are made to utilise banana pseudo stem for making fibre, yarn, fabrics, vermicomposting, liquid fertilizer, quality papers etc. (Mohapatra *et al.,* 2010). Central fibrous portion of pseudo stem is edible and is called as 'core'. It has ~2.5% sugars, along with high quality starch, fiber, calcium, sodium, magnesium, potassium, chlorine, antioxidants and vitamin B_6. There are reports that suggest use of banana pseudo stem as therapeutic agent in treatment of ulcers, diarrhoea, dysentery, diabetes, weight loss, urinary bladder stones, renal pains and prevention/ removal of renal calculi (Kailash,1993; Singh *et al.,* 2007; Patankar *et al.,* 2008; Ghani, 2010; Dixit, 2019). However, human trials are still under progress to understand the mechanism involved and arrive at concrete conclusions. Traditionally, in India, it has been used as a food source and presently, attempts are being made to prepare candies, pickles and nutritive juice blends by adding various natural flavouring agents like ginger or other fruit juices such as grapes (Usha *et al*., 2011; Shiva *et al*., 2018) Although, only two per cent of the pseudo stem biomass is processed, the rest is ultimately being wasted, causing disposal issues.

Fermentation is a traditional science used to convert carbohydrate-rich plant waste biomass into value added products. It plays a prime role in production of bioethanol, beverages like wines and functional foods like probiotics. Though there is a considerable amount of research being done on usage of pseudo stem for bioethanol production (Ingale *et al.,* 2014; Gupta *et al.,* 2019; Tan *et al.,* 2019), its utilization for development of fermented beverages remains untouched. Banana pseudo stem core is rich in sugars, bioactive compounds with nutritional and industrial applicability (Deng *et al.,* 2020), and thus, can be exploited as a unique substrate in beverage industry. The present study focused on prospecting the utility of banana pseudo stem core pulp (BPS) as a novel substrate for development of an alcoholic and a probiotic drink by supplementing the BPS pulp with different cultures of yeast and lactic acid bacterial (LAB) isolates. Based on survey of literature, this is a primordial approach for this substrate.

MATERIALS AND METHODS

Procurement and maintenance of reference organisms

Lactobacillus acidophilus MTCC 10307 (RLAB4) and *Saccharomyces ellipsoideus* NCIM 3200 (RY4) cultures obtained from Microbial Type Culture Collection (MTCC), Chandigarh and National Collection of Industrial Microorganisms (NCIM), Pune, respectively were used as reference cultures for fermentation of pseudo stem core and maintained in respective media

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at 4 °C (Chanchaichaovivat *et al.,* 2007, AdebayoTayo and Akpeji, 2016).

Isolation of yeast and LAB from Banana pseudo stem core (BPS) and development of fermented beverage

Two yeast and LAB strains were isolated from BPS and named as Banana Pseudo Stem Yeast (BPSY1, BPSY2) and Banana Pseudo Stem Lactic Acid Bacteria (BPSLAB1, BPSLAB2), respectively as per standard procedures (Puranik *et al.,* 2019).

Fig. 1 and 2 depict preparation of BPS as substrate and product development, while Table 1 gives result of preliminary study regarding optimized protocols of fermentation parameters using reference organisms. The alcoholic beverages were produced under standardised conditions with isolated yeasts (BPSY1; BPSY2) and reference strain (RY4). Similarly, non-alcoholic beverages were developed using LAB isolates (BPSLAB1; BPSLAB2) and reference strain (RLAB4). The fermented beverages were bottled aseptically and stored at 4 °C until further analysis (Fig. 3) (Puranik, 2017).

Effect on different parameters due to fermentation

The fermented beverages were analysed for different biochemical characteristics like pH (Digital pH meter type MK-VI), TSS (Sakai *et al.,*2000; Ketnawa, 2012), titrable acidity (Srivastava and Kumar, 2002), alcohol content (Caputi *et al.*,1968), total sugars and reducing sugars (Sadasivam and Manickam, 1996). Vitamin C (ascorbic acid) estimation was done by titrimetric method using 2, 6-dichlorophenol indophenol reagent (Ranganna,1996). Additionally, microbial population was also assessed.

Organoleptic evaluation of the developed fermented banana pseudo stem core beverage

The developed fermented beverages were evaluated by selected 10 semi- trained panel members. Twenty-point hedonic scale was considered with slight modifications (Amerine, 1959). The scores were totalled for all the parameters and presented under overall acceptability. The scores 18 to 20 were described excellent (liked extremely), 15 to 17 as Good (very pleasing; liked very much), 12 to 14 as Fair (slightly pleasing; liked mildly), 9 to 11 as Ordinary (Neither pleasant nor unpleasant; neither like nor dislike), 6 to 8 as Poor (slightly unpleasant; disliked mildly), 3 to 5 as Bad (very distinctly unpleasant; disliked very much) and 1 to 2 as Very bad (disliked extremely).

Statistical analysis

The data obtained from the experiments were subjected to statistical analysis using completely randomized design (p<0.01). Web based Agricultural statistics Software Package (WASP-2.0) tool was used to analyse the data and critical difference values were used to locate significant mean difference amongst different treatments.

RESULTS AND DISCUSSION

The use of plant biomass for the preparation of alcoholic and non-alcoholic beverages is gaining significance, particularly in relation to agro-wastes. Traditionally, banana plants are valued as vegetable and therapeutic agent due to their medicinal properties. They are extensively used for making fibre, fabrics, compost, liquid fertilizer etc. (Mohapatra *et al.,* 2010; Dixit, 2019). They also find applications in food industries, especially in preparation of biscuits, pickles, candies and nutritive juices (Sharma *et al.,* 2017; Shiva *et al.,* 2018; Chakraborty *et al.,* 2021). Li *et al.* (2016) used fresh banana pseudo stems as substrate for methane production. There are many reports of utilization of banana pseudo stem for bioethanol production (Gupta *et al.,* 2019; Tan *et al.,* 2019: Ferreira da silva *et al.,* 2020). However, only scantly documentation is available regarding the utility of the pseudo stem towards the development of fermented beverages using yeasts and lactic acid bacteria (LAB). Analyses of biochemical, microbial and sensorial characteristics of beverages are reported and discussed, which provide valuable insights into its promise as a nutritional beverage.

Table 1. Optimized parameters for yeast and lactic acid bacterial fermentation of Banana pseudo stem core (Puranik, 2017).

Parameters	Yeast fermentation	Lactic acid bacterial fermentation
Substrate concentration (%)	25	20
Sugar concentration (%)	20	10
Inoculum level (%)	8	8
Temperature (°C)	28	32
Fermentation period (days)	6	6

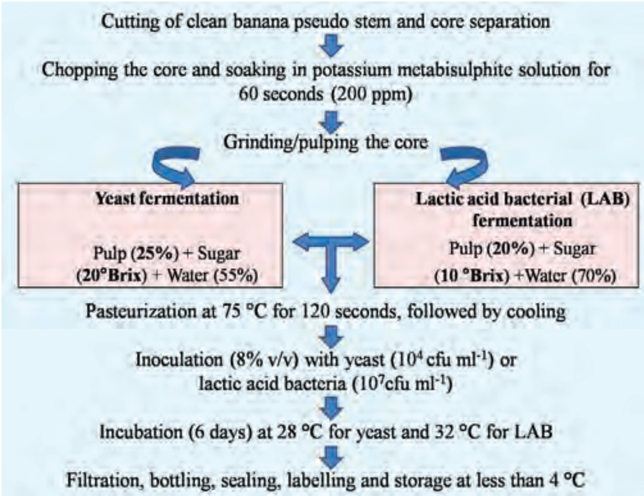

Fig. 1. Procedure for development of fermented beverages from Banana pseudo stem core (Puranik, 2017)

In the present investigation, the pH in both yeast and lactic acid treatments decreased after 6 days, from initial pH of 5.45 and ranged between 3.47 and 4.92 (Table 2). In case of yeasts, the reference strain (RY4) showed highest significant reduction in pH, *i.e.* 3.47, as compared to BPSY1 and BPSY2, which were on par with each other. A similar trend was observed in case of LAB, wherein, reference strain (RLAB4) showed highest reduction in pH (4.53) as compared to the respective indigenous isolates (BPSLAB1 and BPSLAB2). The pH reduces due to production of organic acids during the course of fermentation. The results were in agreement with those reported by Yoon *et al.* (2004) who found a reduction in pH during fermentation of indigenous foods containing tomato pulp with *Lactobacillus casei* and *L. plantarum.* It was also in congruence with present study that both *Saccharomyces ellipsoideus* and *L. acidophilus* remain viable at high acidity and low pH in the fermented BPS.

During fermentation, the sugars are metabolized into alcohol and organic acids by microorganisms. Thus, the reduction in TSS is always desired, since it indicates active and efficient fermentation process. In the present study, initial TSS was set to 20 °Brix for yeast fermentation. It was noted that RY4 recorded highest reduction in TSS (9.90 °Brix) indicating highest efficiency in terms of fermentation as compared to indigenous isolates, which showed significantly poor reduction. Similarly, 10 °Brix was set initially for LAB, which was reduced to 8.80 °Brix after 6 days by RLAB4, followed by BPSLAB1 and BPSLAB2 showing lowest reduction (9.50 and 9.37 °Brix, respectively). A similar trend in reduction of TSS after fermentation was reported by Swami *et al*. (2016) in a novel wine prepared from *Syzigium cumini* stem. The observations illustrated that the native isolates from pseudo stem

Fig. 2. Fermentation set up of Banana pseudo stem core and developed fermented beverages

were less efficient, compared to reference strains used in this investigation.

Titrable acidity was estimated and the values are as given in Table 2. The titrable acidity was 0.15% at the start of experiment that increased as fermentation progressed, which was contrary to results provided by Shiva *et al.* (2018) who concluded decrease in titrable acidity during storage of banana pseudo stem ready-to-drink beverage. The increase in titrable acidity after fermentation period (6 days) could be attributed to metabolism of sugars into different organic acids by microorganisms. RY4 produced lesser titrable acidity (0.29%) as compared to RLAB4 (0.35%). The titrable acidity in pseudo stem core fermented beverage was comparatively less than certain banana (0.85%) and grape wines (0.55 to 0.83%) (Akubor *et al.,* 2003; Pascual *et al.,* 2017).

Alcohol production significantly differed among the yeast strains and ranged from 1.55 to 7.03%. However, highest amount of alcohol (7.03%) was produced by RY4 compared to isolates (BPSY1, BPSY2). Nasir *et al.* (2017) concluded that indigenous yeast isolates could be used for enhanced alcohol production in pineapple and orange. However, their performance is influenced by metabolic diversity of microbial strains and fermentation conditions, which could be a reason for contrasting results in our study. Chaudhary and Karita (2017) showed that their isolates produced different quantities of alcohol even when provided with similar conditions and attributed to their multiplication and sugar conversion capacity. Since LAB do not produce alcohol, only yeast strains were considered for quantification.

Enumeration of yeast and LAB in the beverage was carried out after fermentation and it was observed that population of yeasts was lower as compared to LAB in all the treatments. RY4 showed highest population of 3.6 x 10^3 cfu/ml as compared to other yeast isolates. Similarly, RLAB4 had highest cell count (4.5 x 10^6 cfu/ml) followed by isolate BPSLAB2 (0.36 x 10^6 cfu/ml) and BPSLAB1 (0.31 x 10^6 cfu/ml). LAB population was of utmost importance, since fermented non-alcoholic beverage from BPS had potential to be converted into a probiotic drink. According to the Italian Ministry of Health, daily recommended dose of probiotics is 10^9

Table 2. Effect of different yeasts and lactic acid bacteria on biochemical parameters and microbial counts in the fermented Banana pseudo stem core beverage

Organisms	pH	TSS (°Brix)	Titrable acidity (%)	Alcohol (%)	CFU/ml
Yeasts Fermentation					
Banana Pseudo Stem Yeast isolate 1 (BPSY1)	4.30±0.30^{a}	17.23±0.05^{a}	0.23±0.03^{b}	1.80±0.28^{b}	0.88 x 10^3
Banana Pseudo Stem Yeast isolate 2 (BPSY2)	4.35±0.04^{a}	17.37±0.1^{a}	0.19±0.01^{b}	1.55±0.69^{b}	0.9 x 10^3
Reference yeast 4 (RY4) [*Saccharomyces ellipsoideus*]	3.47±0.14^{b}	9.90±0.5^{b}	0.29±0.04^{a}	7.03±0.76^{a}	3.6 x 10^3
LAB Fermentation					
Banana Pseudo Stem Lactic Acid Bacteria isolate 1 (BPSLAB1)	4.92±0.19^{a}	9.50±0.7^{a}	0.24±0.07^{b}	ND	0.31 x 10^6
Banana Pseudo Stem Lactic Acid Bacteria isolate 2 (BPSLAB2)	4.90±0.14^{a}	9.37±0.01^{a}	0.25±0.06^{b}	ND	0.36 x 10^6
Reference LAB 4 (RLAB4) [*Lactobacillus acidophilus*]	4.53±0.03^{b}	8.80±1.05^{b}	0.35±0.03^{a}	ND	x 10^6

Note: Replications: 5; Initial pH: 5.45, Y- Yeast fermentation, LAB- lactic acid bacterial fermentation; Substrate concentration: 25% (Y), 20% (LAB); TSS: 20°Brix (Y), 10°Brix (LAB); Inoculum: 8%; Fermentation period: 6 days; Temperature: 28 °C (Y), 32 °C (LAB); ND- Not Determined; Different alphabets in the same column denote significant difference

viable cells per serving of 100 ml, a requirement very close to the population in the beverage of present study (10^8 cfu /100ml). However, Food Safety and Standards Authority of India (2022) recommends microbial population of probiotic food to be ≥10^8 cfu/ serving size/ day. The population of *L. acidophilus* in the beverage can be further enhanced to higher levels, by utilization of suitable prebiotics (Hernandez *et al.,* 2012). Some species like *L. acidophilus* are found to be associated with increase in beneficial human gut bacteria like Bifidobacteria at 10^{10} cfu/day (Savard *et al.,*2011). It was found that significant level of LAB population can be maintained in the BPS and thus, proves to be a good substrate for development of a non- dairy based probiotic beverage, especially for lactose intolerant consumers.

Total sugars and reducing sugars are presented in Table 3. It was observed that the total sugars were higher in beverages produced using indigenous isolates as compared to their respective reference strains. The beverage developed by supplementation of yeast isolate BPSY2 contained highest total sugars of 7.04%, followed by that of BPSY1 (6.98%). BPS treated with LAB isolates (BPSLAB1 and BPSLAB2) yielded beverages with higher total sugars, however, with lower reducing sugar content as compared to RLAB4. This could be due to the difference in efficiency and capability of a strain to maintain a high population during the course of fermentation which is supported by a particular substrate. Yoon *et al.* (2004) reported that four LAB strains viz., *L. acidophilus*, *L. plantarum, L. casei* and *L. delbruekii* showed varied changes in sugar contents of tomato juice, with *L. acidophilus* recording higher value. This was due to higher population of *L. acidophilus* over other species. RY4 showed the least total sugar content of 4.87%, with highest reducing sugars (3.30%). This

Table 3. Effect of different yeasts and lactic acid bacteria on sugars and vitamin C of fermented Banana pseudo stem core beverage

Treatments	Total sugars (%)	Reducing sugars (%)
Yeast Fermentation		
Banana Pseudo Stem Yeast isolate 1 (BPSY1)	6.98±0.08^{a}	2.88±0.67^{ab}
Banana Pseudo Stem Yeast isolate 2 (BPSY2)	7.04±0.4^{a}	2.22±0.3^{b}
Reference yeast 4 (RY4) [*Saccharomyces ellipsoideus*]	4.87±0.28^{b}	3.30±0.4^{a}
LAB Fermentation		
Banana Pseudo Stem Lactic Acid Bacteria isolate 1 (BPSLAB1)	5.54±0.05^{a}	1.10±0.5^{b}
Banana Pseudo Stem Lactic Acid Bacteria isolate 2 (BPSLAB2)	5.73±0.05^{a}	1.33±0.1^{b}
Reference LAB 4 (RLAB4) [*Lactobacillus acidophilus*]	5.06±0.05^{b}	2.78±0.1^{a}

Note: Replications: 5; Different alphabets in the same column denote significant difference could be attributed to better enzyme systems in yeast compared to LAB, as it contains invertase enzyme that converts sucrose to reducing sugars like glucose and fructose.

After fermentation, there was an increase in vitamin C content (Fig. 4). This result was in contrast with results of Akubor *et al.* (2003) who reported that vitamin C content in banana wine reduced during fermentation, probably due to oxidation. In this study, initial vitamin C content was 0.09 mg/100 ml beverage and ranged between 0.12 and 0.38 mg, at the end of 6 days. Among yeasts, RY4 produced highest amount of vitamin C viz., 0.19 mg as compared to isolates BPSY 2 (0.17 mg) and BPSY 1 (0.12 mg). Sauer *et al.* (2004) posited that yeasts generally do not produce vitamin C. But in the presence of galactose, they accumulate considerable amounts of ascorbic acid. Since pseudo stem core contains around 2.02% galactose (Li *et al.,* 2010), it substantially increased vitamin C content in the fermented beverage. Thus, the study supports the fact that presence of some precursors or prebiotics in a substrate can enhance vitamin C content to significant levels (Hancock *et al.,* 2000; Zhou *et al*., 2021). LAB produced higher vitamin C than yeasts, with RLAB4 producing highest quantity (0.38 mg). The results were in line with AdebayoTayo and Akpeji (2016), who concluded that ascorbic acid content increased over fermentation period in probioticated pineapple juice. Ascorbic acid also tends to increase shelf life of some beverages, without altering sensory characteristics (Maralanda *et al.,* 2020)

The developed fermented beverages from banana pseudo stem core juice were evaluated by selected

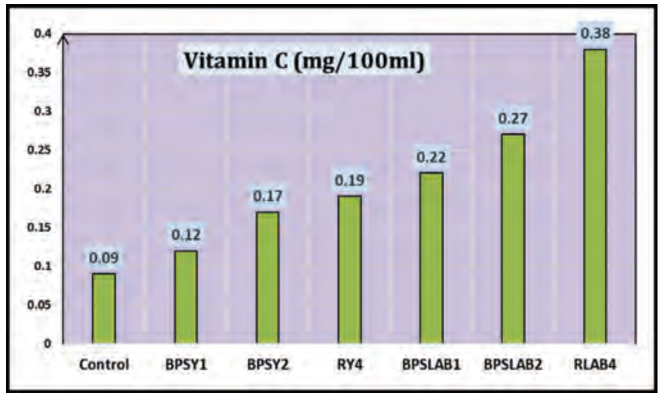

Fig. 3. Vitamin C content after fermentation of banana pseudo stem core by selected microorganisms

10 semi-trained panel members with 20-point hedonic scales (Figs. 4 and 5). Fig. 5 depicts that overall acceptability scores ranged from 12.80 to 16.20. It was observed that highest score was recorded for RY4 (16.20) suggesting that it was best compared to all treatments and fell into 'good quality' category. A similar result was obtained by Cai et al. (2022), who reported that yeast- fermented kiwifruit extracts had higher scores for aroma, bouquet and flavour, as compared to LAB- fermented ones. This was attributed to higher alcohol and ester content in products, that add to their unique sensory properties, especially bouquet and aroma.

Concurrently, the probiotic non-alcoholic beverage developed using reference strain, RLAB4 was also higher (13.9) as compared to indigenous isolates (BPSY1: 12.8; BPSY2: 13.3). However, as suggested

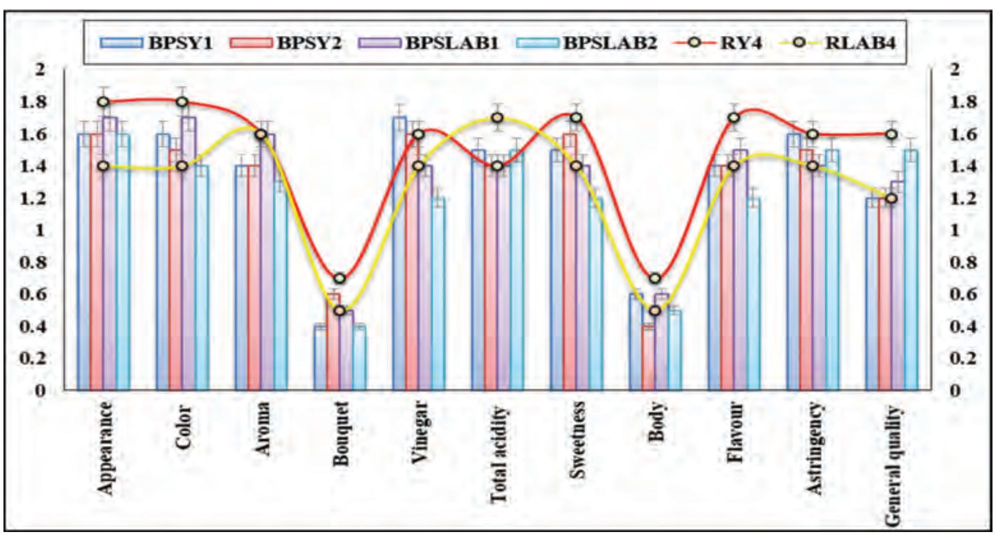

Fig. 4. Organoleptic scores (0-2) of fermented beverages from banana pseudo stem core.

Error bars depict standard deviation (*p*<0.01). BPSY1: Banana Pseudo Stem Yeast isolate 1; BPSY2: Banana Pseudo Stem Yeast isolate 2; RY4: Reference yeast- *Saccharomyces ellipsoideus;* BPSLAB 1: Banana Pseudo Stem Lactic Acid Bacteria isolate 1; BPSLAB 2: Banana Pseudo Stem Lactic Acid Bacteria isolate 2; RLAB 4: Reference LAB, *Lactobacillus acidophilus*

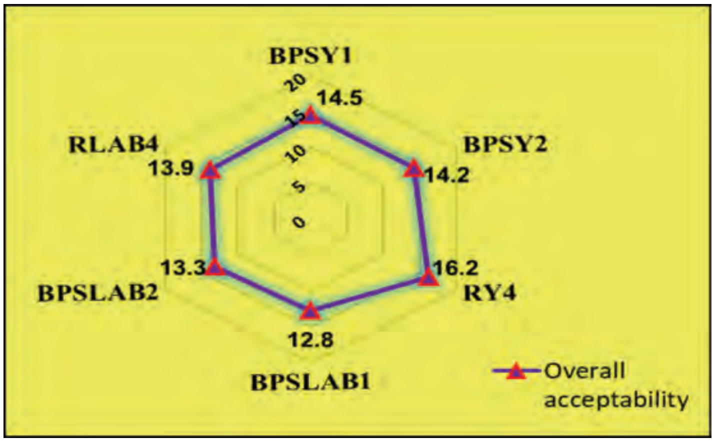

Fig. 5. Overall acceptability scores (0-20) of fermented beverages from banana pseudo stem core

BPSY1: Banana Pseudo Stem Yeast isolate 1; BPSY2: Banana Pseudo Stem Yeast isolate 2; RY4: Reference yeast- *Saccharomyces ellipsoideus;* BPSLAB 1: Banana Pseudo Stem Lactic Acid Bacteria isolate 1; BPSLAB 2: Banana Pseudo Stem Lactic Acid Bacteria isolate 2; RLAB 4: Reference LAB, *Lactobacillus acidophilus.* Overall acceptability is an aggregate of all the parameters of Fig.4

by scores, they were of 'fair quality'. Further, it can be inferred that all beverages were pleasing and liked by the panel members. Though hedonic scales based organoleptic evaluations are beneficial for knowing the acceptability of consumers, they are highly subjective, varying from person to person with wide scope of questioning (Amerine *et al.,*1959: Lawless *et al.,*1997). Similar kind of acceptability was observed for different fermented beverages derived from under-utilized substrates (Mohanty *et al.,*2006: Khandelwal *et al.,* 2012; Genevois *et al.,* 2016). Nedanovska *et al.* (2022) also employed 20- point hedonic scale for adjudging overall acceptability of whey- fruit based beverages and recorded scores as high as 18.20 for their products.

In conclusion, banana pseudo stem is a huge waste in the form of lignocellulose biomass and is difficult to dispose. Though BPS has applications in bioethanol production, its usage in fermented consumables had remained unexplored. It possesses high content of sugars and minerals, which makes it a novel and potent substrate for production of non-dairy based probiotic and alcoholic beverage, using *L. acidophilus* and *S. ellipsoideus*. The present study forms a baseline for utilizing and converting a high volume, nutrient rich biomass into fermented beverages with fair to good overall acceptability. It was found that treatment with selected inocula also improved vitamin C content in the beverages. The study might make a great idea for upcoming entrepreneurs, especially banana growing farmers, since novel and cheap substrates are current requirement in beverage industry. However, extended studies are needed for quality improvement and probiotication of the beverage by blending with suitable prebiotics and fruit juices.

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Authors' contribution

Conceptualization and designing of the research work (MKB, SVC, SP); Execution of lab experiments and data collection (SP); Analysis of data and interpretation (SP, SKS, MM); Preparation of the manuscript (SP, SVC, SKS, MM)

LITERATURE CITED

AdebayoTayo B and Akpeji S 2016. Probiotic viability, physicochemical and sensory properties of probiotic Pineapple juice. *Fermentation* **2**: 20-31.

Ahmad T and Danish M 2018. Prospects of banana waste utilization in wastewater treatment: A review. *J. Environ. Manage*. **206**: 330-48.

Akubor P I, Obio S O, Nwadomere K A and Obiomah E 2003. Production and quality evaluation of Banana wine. *Plant Foods Hum Nutr* **58**: 1-6.

Amerine M A, Roessler E B and Filipello F 1959. Modern sensory methods of evaluating wine. Hilgardia **28**: 477-567.

Cai L, Wang W, Tong J, Fang L, He X, Xue Q and Li Y 2022. Changes of bioactive substances in lactic acid bacteria and yeasts fermented kiwifruit extract during the fermentation. *LWT* **164**: 113629.

Caputi A, Ueda J and Brown T 1968. Spectrophotometric determination of chromic complex formed during oxidation of alcohol. *Am J Enol Vitic* **19**: 160-65.

Chakraborty R, Sabruna S, Roy R, Majumdar S and Roy S 2021. Banana pseudostem substitution in wheat flour biscuits enriches the nutritional and antioxidative properties with considerable acceptability. *SN Appl Sci* **3**(75).

Chanchaichaovivat A, Ruenwongsa P and Panijpan B 2007. Screening and identification of yeast strains from fruits and vegetables: Potential for biological control of postharvest chilli anthracnose (*Colletotrichum capsici*). *Biol Control* **42**: 326-35.

Chaudhary A and Karita S 2017. Screening of yeast isolates from flowers for effective ethanol production. *Turk J Biol* **41**: 890-900.

Deng G, Sheng O, Bi F, Li C, Dou T, Dong T, Yang Q, Gao J, Zhong X, Peng M, Yi G, He W and Hu C 2020. Metabolic profiling in banana pseudo-stem reveals a diverse set of bioactive compounds with potential nutritional and industrial applications. *Phyton* **89**: 1102-30.

Dixit A 2019. Banana stem: An under-utilised part of the plant. *Int J Sci Res* **8**: 24-25.

FAOSTAT2021.http://www.fao.org/economic/est/estcommodities/bananas/bananafacts/en/#.Xp9gR8gzbIU Accessed on 10 October 2019.

Ferreira da Silva I, Reis Fontinelle Souto L, Collins S R A, Elliston A, de Queiroz, J H and Waldron K W 2020. Impact of Hot Water and Alkaline Pre-treatments in Cellulosic Ethanol Production from Banana Pseudostem. *Bioenergy Res* **13**: 1159–70.

Food Safety and Standards Authority of India, Ministry of Health and Family Welfare, India, Notification dated 28th June, 2022, The Gazette of India. REGD. NO. 34456/2022. https://fssai.gov.in/upload/uploadfiles/files/Draft_Notification_Health_29_06_2022.pdf

Genevois C, Flores S and de Escalada Pla M 2016. Byproduct from pumpkin (*Cucurbita moschata* Duchesne ex poiret) as a substrate and vegetable matrix to contain *Lactobacillus casei*. *J Funct Foods* **23**: 210–19.

Ghani A 2010. Medicinal plants of Bangladesh: Chemical constituents and uses. *J Appl Pharm Sci* **1**:14-20.

Gupta G, Baranwal M, Saxena S and Reddy M S 2019. Utilization of Banana stem juice as a feedstock material for bioethanol production. Clean - Soil Air Water **47**: 1-5.

Hancock R D, Galpin J R and Viola R 2000. Biosynthesis of L-ascorbic acid (vitamin C) by *Saccharomyces cerevisiae*. FEMS *Microbiol Lett* **186**(2): 245–50.

Hernandez-Hernandez O, Muthaiyan A, Moreno F J, Montilla A, Sanz M L and Ricke S C 2012. Effect of prebiotic carbohydrates on the growth and tolerance of *Lactobacillus*. *Food Microbiol* **30**: 355–61.

Hoben H J and Somasegaran P 1982. Comparison of the pour, spread, and drop plate methods for enumeration of *Rhizobium* spp. in inoculants made from pre-sterilized peat. *Appl Environ Microbiol* **44**: 1246-47.

Ingale S, Joshi S J and Gupte A 2014. Production of bioethanol using agricultural waste: Banana pseudo stem. *Braz J Microbiol* **45**: 356-71.

Kailash P, Bharathi K and Srinivasan K 1993. Evaluation of *Musa paradisiaca* Linn. Cultivar “Puttubale” stem juice for antilithiatic activity in albino rats. *Indian J Physiol Pharmacol* **37**: 337-41.

Ketnawa S, Chaiwut P and Rawdkuen S 2012. Pineapple wastes: A potential source for bromelain extraction. *Food Bioprod Process* **90**: 385-91.

Khandelwal P, Upendra R S, Kavana U, Sahithya S and Sateesh 2012. Preparation of blended low alcoholic beverages from under-utilized millets with zero waste processing methods. *Int J Fermented Foods* **1**: 77-86.

Lawless H, Liu Y F and Goldwyn C 1997. Evaluation of wine quality using a small-panel hedonic scaling method. *J Sens Stud* **12**: 317-32.

Li C, Liu G, Nges I A, Deng L, Nistor M and Liu J 2016. Fresh banana pseudo-stems as a tropical lignocellulosic feedstock for methane production. *Energy Sustain Soc* **6**(1).

Li K, Fu S, Zhan H, Zhan Y and Lucia L 2010. Analysis of the chemical composition and morphological structure of Banana pseudo stem. *Bioenergy Res* **5**: 576-85.

Maralanda S M T A, Gamage K G R, Perumpuli B, Karunarathna W K D S, Perera M A R I and Wijesuriya A 2020. Shelf life of pineapple and lime-flavoured, ascorbic acid-added and ready-to-serve sugarcane juice beverage. In *Sugar and sugar derivatives: changing consumer preferences,* Mohan N, Singh P (eds).. Springer, Singapore.

Mohanty S, Ray P, Swain M R and Ray R C 2006. Fermentation of Cashew (*Anacardium occidentale* L.) apple into wine. *J Food Process Preserv* **30**: 314–22.

Mohapatra D, Mishra S and Sutar N 2010. Banana and its byproducts utilization: An overview. *J Sci Ind Res* **69**: 323-29.

Nasir A, Rahman S S, Hossain M M and Choudhury N 2017. Isolation of *Saccharomyces cerevisiae* from pineapple and orange and study of metal’s effectiveness on ethanol production. *Eur J Microbiol Immunol* **7**: 76–91.

Nedanovska E, Jakopović KL, Daniloski D, Vaskoska R, Vasiljevic T and Barukčić I 2022. Effect of storage time on the microbial, physicochemical and sensory characteristics of ovine whey□based fruit beverages. *Int. J. Food Sci. Technol*. **57**: 5388-98.

Pascual O, Pons-Mercade P, Gombau J, Ortiz-Julien A, Heras J M, Fort F and Zamora F 2017. Study of the effectiveness of a strain of *Saccharomyces cerevisiae* selected for the production of wines with higher acidity and lower alcoholic strength. Bio Web of Conferences. doi:10.1051/bioconf/20170902002.

Patankar S, Dobhada S, Bhansali M, Khaladkar S and Modi J A 2008. Prospective, Randomized, Controlled Study to Evaluate the Efficacy and Tolerability of Ayurvedic Formulation “Varuna and Banana Stem” in the Management of Urinary Stones. *J Altern Complement Med* **14**: 1287–90.

Puranik S, Munishamanna K B and Sruthy K S 2019. Isolation and Characterization of Lactic Acid Bacteria from Banana Pseudostem. *Int J Curr Microbiol Appl Sci* **8**: 39-47.

Puranik S 2017. Microbial processing of banana pseudo stem core for development of fermented beverage. Dissertation, University of Agricultural Sciences, Bengaluru, India.

Ranganna S 1996. Handbook of analysis and quality control for fruits and vegetable products. Tata McGraw-Hill Pub. Co. Ltd., New Delhi.

Sadasivam S and Manickam A 1996. Biochemical Methods. New Age Int. (P) Ltd. Publishers, New Delhi.

Sakai K, Murata Y, Yamazumi H, Tau Y, Mori M, Morjguchi M and Shira Y 2000. Selective proliferation of lactic acid bacteria and accumulation of lactic acid during open fermentation of kitchen refuse with intermittent pH adjustment. *Food Sci Technol Res* **6**: 140-45.

Sauer M, Branduardi P, Valli M and Porro D 2004. Production of L-ascorbic acid by metabolically engineered *Saccharomyces cerevisiae* and *Zygosaccharomyces bailii*. *Appl Environ Microbiol* **70**: 6086–91.

Savard P, Lamarche B, Paradis M, Thiboutot H, Laurin E and Roy D 2011. Impact of *Bifidobacterium animalis* subsp. *lactis* BB-12 and *Lactobacillus acidophilus* LA-5 containing yoghurt, on faecal bacterial counts of healthy adults. *Int J Food Microbiol* **149**: 50-57.

Sharma M, Patel S N, Sangwan R S and Singh S P 2017. Biotransformation of banana pseudo stem extract into a functional juice containing value added biomolecules of potential health benefits. *Indian J Exp Biol* **55**: 453-62.

Shiva K N, Adiyaman P, Naik R and Marimuthu N 2018. Development and standardisation of banana pseudostem based novel functional blended Ready to Drink (RTD) beverages and studies nutritional changes during storage. LS- *Int J Life Sci* **7**: 151-58.

Singh S K, Kesari A N, Rai P K and Watal G 2007. Assessment of glycemic potential of *Musa paradisiaca* stem juice. *Indian J Clin Biochem* **22**: 48–52.

Srivastava R P and Kumar S 2002. Fruit and Vegetable Preservation: Principles and practices. Bio-Green Books, India.

Swami U, Rishi P and Soni S K 2016. A non-conventional wine from stem of *Syzygium cumini* and statistical optimization of its fermentation conditions for maximum bioactive extraction. *Int J Food Ferment Technol* **6**: 25-34.

Tan J S, Phapugrangkul P, Lee C K, Lai Z W, Abu Bakar M H and Murugan P 2019. Banana frond juice as novel fermentation substrate for bioethanol production by *Saccharomyces cerevisiae*. *Biocatal Agric Biotechnol* **101293**: 1-8.

The Italian Ministry of Health. www.salute.gov.it/imgs/C_17_pubblicazioni_1016_ulterioriallegati_ulterioreallegato_0_alleg.pdf Accessed 10 October 2019.

Usha R, Menon L and Gomathy G 2011. Development and quality assessment of value added plantain stem juice incorporated with grape juice. *Indian J Nat Prod Resour* **2**: 204-10.

Yoon K Y, Woodams E E and Hang Y D 2004. Probiotication of tomato juice by lactic acid bacteria. *J Microbiol* **42**: 315-18.

Zhou M, Bi Y, Ding M and Yuan Y 2021. One-step biosynthesis of vitamin C in *Saccharomyces cerevisiae*. *Front Microbiol* **12**: 643472.