



Screening of physicochemical and functional attributes of fermented beverage (wine) produced from local mango (*Mangifera indica*) varieties of Uttar Pradesh using novel *saccharomyces strain*

Vikash Patel¹ · Abhishek Dutt Tripathi¹ · Kundan Singh Adhikari² · Anurag Srivastava³

Revised: 17 July 2020 / Accepted: 13 August 2020 / Published online: 1 September 2020
© Association of Food Scientists & Technologists (India) 2020

Abstract Mango (*Mangifera Indica* L.) is a major tropical fruit rich in sugar, organic acids and flavonoids, making it suitable fruit for wine making. In the present study, five varieties of mango (*Baganpalli*, *Langra*, *Dashehari*, *Alphonso*, and *Totapuri*) were utilized for wine production using two different yeast strains namely, *Saccharomyces cerevisiae* MTCC 178 and isolated yeast. The physicochemical analysis of wine produced from chosen mango varieties showed that North Indian local mango variety (*Dashehari*) gave better results in terms of organoleptic and functional attributes. The *Saccharomyces cerevisiae* MTCC 178 treated *Dashehari* wine possessed $6.1 \pm 0.26\%$ TSS, $2.1 \pm 0.08\%$ reducing sugar, 0.657% titratable acidity, $0.11 \pm 0.00\%$ volatile acidity, 12% ethanol (v/v) and pH 3.7 ± 0.10 comparable to *Baganpalli* mango wine. HPLC analysis of *Saccharomyces cerevisiae* MTCC 178 inoculated *Dashehari* mango wine revealed the presence of primarily; gallic acid (RT-4.4 min), Galloyl-A-type, procyanidin (RT-5.2 min), 2,2,6-Trimethyl-6-vinyl-tetrahydropyran (RT-8.91 min), β -Pinene (RT-11.47 min) and Caffeoyl-quinic acid (RT-12.15 min) showing potential antioxidant, anti-cancerous, anti-inflammatory and antimicrobial properties. The local mango varieties wine showed significant ($p < 0.05$) physicochemical properties,

antioxidant potential and ethanol content comparable to *Baganpalli* wine and was cost effective.

Keywords Mango (*Mangifera indica*) wine · Mango varieties · Yeast strains · Physicochemical analysis · Functional attributes · Cost-effective

Introduction

Nowadays, the whole world is facing the Coronavirus disease (COVID-19, caused by the novel coronavirus SARS-CoV-2) threat and declared as a pandemic by WHO on 11 March 2020 (WHO report 2020). There is urgent need to combat the economic crisis in the era of the COVID-19 pandemic, by developing functional foods fortified with bioactive compounds and antioxidants that promote health and immune system of consumers (Galnakis 2020). In nature, fruits are most common source of antioxidants, flavonoids and polyphenols, which plays vital role as immunity booster and prevention of chronic diseases like cancer and AIDS (Kaleem et al. 2015). Tropical fruits like mangoes, pine apple and guava possess huge amount of functional ingredients such as bioactive amines which prevents the cardiovascular disease, neural and gastrointestinal disorders (Gloria et al. 2011). In India, production of mango (*Mangifera indica* L) is very high and it occupies 45.10% of the total world's production (NHD 2015). Uttar Pradesh is leading mango producing state in India, contributing 23.06% of total mango production. The total mango production in Uttar Pradesh was found to be 4540.23 thousand MT in 2016–2017 (National Mango Database 2018). In Uttar Pradesh, there are several mango varieties such as *Dashehari*, *Langra*, *Chausa*, *Ratole* and *Bombay*, but leading mango varieties are *Langra* and

✉ Abhishek Dutt Tripathi
abhi_itbhu80@rediffmail.com

¹ Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh 221005, India

² Department of Biotechnology, National Taiwan University, Taipei, Taiwan

³ Department of Molecular Biotechnology, University of Turin, Turin, Italy

Dashehari. *Dashehari* is one of the most liked varieties in India owing to its high aromatic flavor. It possess an appropriate mixture of sourness and sweetness, which result in high taste. Mango fruit contains carbohydrate (starch and sugar), organic acid, lipid, pigment, and volatiles, phenolics and antioxidants (Maldonado-Celis et al. 2019). Substantial phenolic compounds found in mangoes are mangiferin, quercetin, gallic acid, benzoic acid, kaempferol, anthocyanins, and protocatechuic acid (Palafox-Carlos et al. 2012). These phenolics plays significant role in preventing cardiovascular diseases, atherosclerosis and decreases the risk of cancer (Pierson et al. 2015).

However, a huge quantity of mango wasted annually because of its short postharvest life. To prevent this huge postharvest loss, mangoes may be processed into diversified products like slices, pulp, jam, squash, nectar, juice, RTS beverages, mango leather etc.

The post-harvest loss of fruits can be minimized by processing them into value added food products such as fermented beverage. Fruit wines are fermentative product, which possess high commercial importance. Wine production begins with the fermentation process followed by aging. Wine is preferred over other alcoholic beverages, as wine is not subjected to distillation process; loss of nutrients is minimum and posses comparable nutritive value as in original fruit (Versari et al. 2015). These are nutritive, tastier and mild stimulants, which substantially utilizes grapes, elderberry or black currant in wine production. Grapes are conventional and generally preferred for wine production owing to its nutritious and desirable aroma and flavor. Although, grapes are preferred raw material for wine production, the availability of grapes is a concern. This allows the opportunity to search for other fruits, especially locally available fruits having low cost and reluctant availability as an alternative (Reddy and Reddy, 2005). It has been previously reported that the ethanol and aromatic components content in mango wine is comparable to those of grape (Reddy et al. 2011). Although, nascent report are available on utilization of south Indian mango variety (*Baganpalli*) in wine making but not much research work done on local mango variety of Uttar Pradesh. The nutritive value and quality of wine depends upon the inoculum yeast (Coulibely et al. 2016). The non-thermal food processing such as thermo-sonication, ultra high pressure (UHP) and enzyme assisted extraction retain the nutritional and phenolic profile of fruit juice and processed products (Dars et al. 2019). The nutritional and phytochemical composition of mangoes varies with varieties, ripening stages and postharvest storage (Maldonado-Celis et al. 2019). In the present study an attempt was made to study, the physicochemical and functional attributes of fermented beverage (wine) produced from local mango

(*Mangifera indica*) varieties of Uttar Pradesh using two different yeast cultures.

Materials and methods

Raw materials and chemicals

The five varieties of mango (*Mangifera indica* L) fruits namely; *Baganpalli*, *Langra*, *Dashehari*, *Alphonso*, and *Totapuri* were purchased from the local market of Varanasi (Uttar Pradesh, India). All the chemicals and reagents were of analytical grade and were procured from Himedia, Mumbai, India.

Starter culture and maintenance media

The freeze-dried *Saccharomyces cerevisiae* MTCC 178 strain was procured from Microbial Type Culture Collection (MTCC), Institute of Microbial Technology, Chandigarh (India). Another yeast isolate (ISY) was obtained from Department of Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The freeze-dried culture were revived in peptone water, followed by streaking on PDA plates and incubated at 25 ± 0.2 °C for 48 h. After 48 h, pure colonies were re-cultured in the sterilized growth medium.

Inoculum preparation

For inoculum preparation, one inoculation loop of *Saccharomyces cerevisiae* MTCC 178 and ISY colonies were transferred in 250 mL conical flask, comprising 100 mL of mango pulp obtained from different mango varieties individually. The inoculated mango pulp then incubated at 25 ± 0.2 °C for seven days. The appearance of bubbles and over ripened fruity odor in pulp showed completion of inoculum preparation.

Preparation of must for fermentation

Exactly 1 kG each of the mango varieties were weighed. The fruit fermentation process was started by preparing must. The selected mango varieties were then sorted, washed with distilled water and peeled off manually using a knife. After peeling and destoning, fruits were chopped into smaller pieces and then transferred in pulper (Bajaj, India) for pulp extraction. The extracted pulp was then homogenized using laboratory blender. The juice from pulp extracted by squeezing pulp through a muslin cloth. The extracted juice then utilized for fermentation process (Fig. 1). The extracted juice then transferred into 250 mL clean conical flask and mixed with distilled water (1:1,

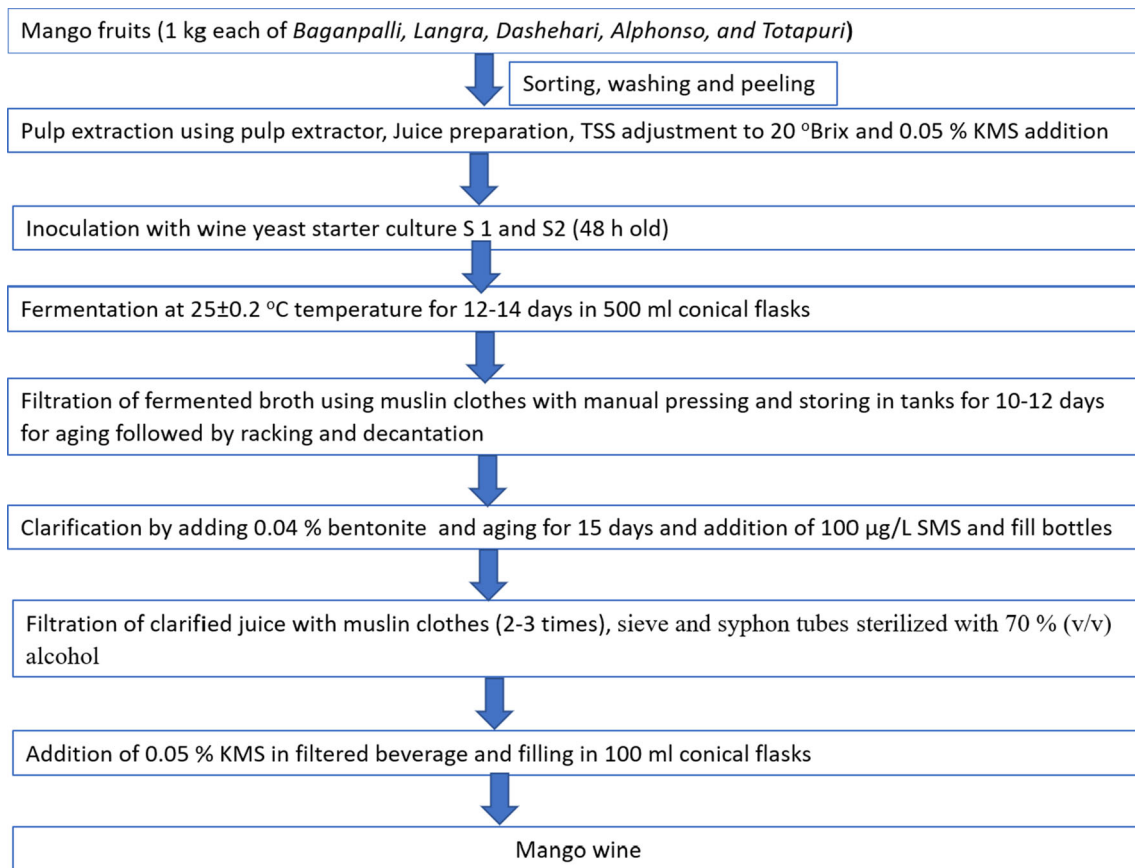


Fig. 1 Production of mango wine using different mango varieties by fermentation using ISY (S1) and *Saccharomyces cerevisiae* MTCC 178 (S2) strains

w/v). In order to maintain the initial TSS at 20 °Brix, 0.107, 0.122, 0.117, 0.116 and 0.134 kG of sugar added in the must prepared from *Alphonso*, *Langara*, *Dashehari*, *Baganapalli* and *Totapuri* varieties, respectively with vigorous stirring. Then, 0.05% (w/v) of potassium metabisulphate (KMS) added in the each must samples prior to inoculation of yeast culture. KMS serve as a sterilizer and prevents fermentation before the addition of the yeast starter.

Fermentation

The batch fermentation was carried out in 500 mL sterile conical flasks and each flask contained 100 mL of juice obtained from different mango varieties. 2.5 mL of *Saccharomyces cerevisiae* MTCC 178 (S1) and ISY (S2) inoculum added in the must samples and incubated at 25 °C for 15 days. After 15 days, the fermented juices filtered through muslin clothes with manual pressing. The extracted juice then clarified by bentonite (a clarifying agent). The clarifying agent prepared by dissolving 500 g of bentonite in 2 l of boiling water and stirred properly to a gel form. This was then allowed to stand for 24 h. Then,

150 g of the gel-like bentonite was added into each of the wine samples followed by stirring to get it dissolved properly. After 15 days of clarification, filtration was done using muslin cloth, sieve and syphon tubes sterilized with 70% (v/v) alcohol. All the wine samples were syphoned into the sieve containing four layers of muslin cloth. The residues removed and the filtrates collected for further physicochemical analysis.

Physicochemical analysis

The physicochemical properties of juice extracted from different mango varieties and wine developed from them were analyzed. The wine samples produced by using ISY and *Saccharomyces cerevisiae* MTCC 178 strain were categorized as S1 and S2 samples, respectively. The juice yield, which is an important factor in wine production, was measured as the total quantity of juice obtained from one kilogram of fruit.

TSS was determined by a refractometer (RFM970, BS, India). pH was determined by pH meter (Fischer Scientific, USA) and reducing sugar estimation was done by DNS method. Titratable acidity was measured by AOAC (2000)

method. Volatile acidity (VA) determined by taking 10 mL of the wine sample and collecting 75 mL of the distillate in a 250 mL conical flask. The distillate was titrated against 0.1 N NaOH and 1% phenolphthalein solution used as indicator, until a pink color persisted. The amount of NaOH used was noted (titer value) and used for calculation as described using AOAC (2000) method as follows:

$$\text{VA (in g/L of acetic acid)} = (\text{Sample size / titer value}) \times (0.06).$$

Ethanol estimation

Ethanol content was estimated using Gas chromatography (GC). The fermented broth were centrifuged at 5000 g for 10 min at 4 °C in cold centrifuge (Sigma Aldrich, USA). The supernatant collected was mixed with propanoic acid (1:1. v/v) and heated at 100 °C for enhancing the volatility. For GC analysis, 2 µL of samples was injected with the help of micro-syringe (Hamilton, Germany). Nucon gas chromatograph instrument was used with 5% Carbowax 20 m glass column on Carbopack-B 80/120 mesh. Nitrogen used as a carrier gas with a flow rate of 20 mL/min. The eluted compounds detected by FID detector. The fuel gas was hydrogen with a flow rate of 40 mL/min, and the oxidant was air, with a flow rate of 40 mL/min. The analytes then identified based on their retention time (RT).

Flavonoids determination

Selection of the variety for determination of flavonoids was made on the basis of ethanol production. The flavonoids were determined by HPLC (Shimadzu, Japan) equipped with 515 HPLC pump and a C-18 column connected to a UV detector. The column was eluted at 40 °C with a degassed aqueous mobile phase containing 0.1% sulphuric acid at a flow rate of 0.4 mL/min. Flavonoids identified based on their retention time. For HPLC analysis, the sample preparation was done by centrifuging the clarified sample in cold centrifuge at 8000 rpm for 15 min at 4 °C. The supernatant obtained further filtered by membrane filter with mesh size of 0.22 microns (Millipore, USA). 2.0 µL of filtered sample was then injected in HPLC column through micro syringe (Hamilton, Germany).

Statistical analysis

The completely randomized analysis of variance (ANOVA) was used as described by Winner (2004) for data analysis. The mean separation and comparison was done using SPSS version 16.0 software. The significance

was accepted at value ($p < 0.05$) and results were expressed as mean \pm standard deviation from the mean.

Results and discussion

The present study investigated the influence of two yeasts namely; *Saccharomyces cerevisiae* MTCC 178 and isolated *Saccharomyces* yeast (ISY) on the quality of wine produced using different mango varieties like *Alphonso*, *Langra*, *Dashehari*, *Banganapalli* and *Totapuri*.

Physicochemical properties of mango juice

The juice yield and physicochemical properties of different varieties of mango juice were analyzed (Table 1). All the mango varieties showed significant ($p < 0.05$) variation in their physicochemical properties. *Banganapalli* & *Totapuri* variety gave the maximum juice yield, whereas, *Alphonso* and *Langra* showed the minimum juice yield (Table 1). Juice yield is an important parameter in wine production as it depicts the final quantity of the wine. Fruits with high juice yield were preferred for wine production relative to low juice yielding fruits for economic purposes. The minimum and maximum pH value of 3.3 ± 0.35 to 4.6 ± 1.30 were observed in *Totapuri* and *Langra* varieties, respectively (Table 1). The pH of the fruit juice plays an important role in flavor promotion as well as a preservative (Akhtar et al. 2010). The main prerequisite for fermentation is sugar content in the fruit juice. The total soluble solids (TSS) of the mango juice ranged from 13.26 ± 1.12 to 18.60 ± 1.27 °Brix. The minimum and maximum TSS was observed in *Totapuri* and *Alphonso* varieties, respectively (Table 1). The TSS value of *Dashehari* and *Langra* were comparable to *Banganapalli* varieties. However, the TSS value for local varieties (*Dashehari* and *Langra*) was lesser in comparison to previous findings of Rajendra kumar et al. (2001) who reported that Northern India *Dashehari* variety possessed high TSS of 25.75% with a total sugar content of 21.2%. The significant ($p < 0.05$) difference in TSS in same cultivar occurred due to demographic variation and harvesting performed in different months. The reducing sugar content of the *Dashehari* and *Langra* mango juice was comparable to the *Banganapalli* (Table 1). Although, maximum and minimum reducing sugar content of 17.40 ± 1.0 to $12.50 \pm 1.10\%$ was observed in *Banganapalli* and *Totapuri* varieties, respectively (Table 1). The titratable acidity (TA) as tartaric acid varied from 0.32 to 0.48%. The TA of *Langra* and *Dashehari* varieties showed insignificant ($p > 0.05$) variation and was in close proximity to *Banganapalli* variety (Table 1).

Table 1 Physicochemical properties of juice of different mango varieties

Mango varieties	Juice yield (ml/Kg)	PH	TSS (°B)	Reducing sugar (% w/v)	TA [#] (%)
<i>Alphonso</i>	550 ± 15 ^{aw*}	3.7 ± 0.80 ^{aw*}	18.60 ± 1.27 ^{bx*}	16.60 ± 0.80 ^{aw*}	0.44 ± 0.01 ^{aw**}
<i>Langara</i>	560 ± 12 ^{ax**}	4.6 ± 1.30 ^{aw**}	15.57 ± 0.72 ^{bw**}	14.20 ± 1.20 ^{bx*}	0.32 ± 0.03 ^{aw**}
<i>Dashehari</i>	580 ± 14 ^{aw*}	4.1 ± 0.95 ^{bw*}	16.53 ± 0.92 ^{bw**}	16.20 ± 1.40 ^{az*}	0.39 ± 0.00 ^{aw**}
<i>Banganapalli</i>	600 ± 17 ^{ay*}	4.2 ± 0.85 ^{bw**}	16.72 ± 1.28 ^{bx*}	17.40 ± 1.0 ^{cw*}	0.34 ± 0.06 ^{aw*}
<i>Totapuri</i>	590 ± 20 ^{az*}	3.3 ± 0.35 ^{az***}	13.26 ± 1.12 ^{az**}	12.50 ± 1.10 ^{aw*}	0.48 ± 0.04 ^{aw**}

#As Tartaric acid; †As acetic acid; First superscript letter (a-d) shows the significant difference ($p < 0.05$) among a particular row, second superscript letter (w-z) shows the significant difference ($p < 0.05$) among a particular column for a specific attribute. Results are expressed as $n = 3$, $SD \pm 0.05$, * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Physicochemical properties of mango wine

The pH level affects the aroma, flavor and mouthfeel of the wine. The pH value was significantly ($p < 0.05$) affected by inoculum type. S1 samples showed significant ($p < 0.05$) pH decrease in comparison to S2 in each mango variety wine (Table 2). The maximum pH values of 4.0 ± 0.15 and 4.1 ± 0.17 was observed in both the treatments (S1 and S2) of *Langra* wine. Similarly, minimum pH value was observed in *Totapuri* wine in both S1 and S2 treated samples (Table 2). *Dashehari* wine showed pH value of 3.7 in S2 sample, which was closer to *Banganapalli* variety wine. It is previously reported, that optimum pH for wine is 3.5–3.8 (Reddy and Reddy, 2005). The pH value of *Alphonso* and *Totapuri* variety wine was lower in comparison to local varieties. The extreme low pH (< 3.2) value imparts acidic taste and is undesirable in wine making. The TSS content varied significantly with different inoculums in all the mango varieties wine. The maximum TSS score of 13.8 ± 0.78 & $13.4 \pm 0.47\%$ was observed in *Langra* wine with S1 and S2 samples, respectively. The minimum TSS score of 5.2 ± 0.26 & $6.1 \pm 0.26\%$ were observed in S2 samples of *Banganapalli* and *Dashehari* wine, respectively (Table 2). The significant ($p < 0.05$) reduction in the TSS during wine production may be due to the faster yeast activity that converted sugars into alcohol in lesser time. Previously, a similar finding was reported in peach-based wine (Joshi et al. 2005).

The sugar content of a given fruit is necessary for wine production, as magnitude of sugar fermentation is the measure of alcohol yield. Similarly, reducing sugar content also affects the aroma and flavor of wine, which are the main factors that determine its quality and value (Molina et al. 2007). The reducing sugar content changed significantly ($p < 0.05$) in S2 samples. The maximum reduction in reducing sugar content was estimated in *Banganapalli* and *Dashehari* wine with S1 sample (Table 2). The higher the reduction in reducing sugar

content more is ethanol production. The low reducing sugar content (2.0 g/L) of *Dashehari* variety deduced that in S2 sample, conversion of sugar to alcohol was higher in comparison to other mango varieties (Table 2).

The present study also revealed a consistent increase in the TA of all the mango wines throughout the fermentation process. The TA increased significantly after fermentation in both group of samples. Among S1 samples, maximum TA score observed in *Alphonso* wine, i.e., 0.650% and *Dashehari* wine showed a minimum score, i.e., 0.615% (Table 2). The maximum TA observed in *Banganapalli* wine, i.e., 0.698% and *Dashehari* wine had a minimum score, i.e., 0.657, among S2 samples (Table 2). The TA of fine quality wine is expected to be in the range of 0.5 to 1.0% (Chilaka et al. 2010). The above finding clearly suggest that S2 samples showed better acceptability as the yeast culture showed better resistant towards acidic condition and it also facilitates the shelf life of product as higher acidity restricts the bacterial growth and poses tremendous preservative properties. Simultaneously, it can be clearly deduced from the Table 2, that S2 treated *Dashehari* mango wine showed optimal TA value.

The maximum and minimum volatile acidity (VA) of 0.52 ± 0.00 and $0.12 \pm 0.00\%$ was observed in *Totapuri* and *Langra* wine in S1 samples. Similarly, maximum and minimum VA of 0.45 ± 0.13 and $0.11 \pm 0.00\%$ were observed in *Totapuri* and *Dashehari* wine, respectively in S2 samples (Table 2). Volatile acidity affects the aroma and flavor of the wine. At higher levels of acetic acid, it causes spoilage of product; also may stimulate the formation of unpleasant volatile compounds viz. ethyl acetate that has an odor like fingernail polish (Moreno and Polo 2005). This clearly suggests that S2 samples of *Dashehari* wine possessed better organoleptic properties and more shelf life owing to their low VA.

Table 2 Estimation of physicochemical properties of mango wine produced from different mango varieties by fermentation using ISY (S1) and *Saccharomyces cerevisiae* MTCC 178 (S2) strains

Mango varieties	PH		TSS (°B)		Reducing sugar (% w/v)		TA (%)		VA (in g/L of acetic acid)	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
<i>Alphonso</i> wine	3.2 ± 0.10 ^{aw*}	3.4 ± 0.10 ^{aw*}	11.0 ± 0.77 ^{bw*}	10.2 ± 0.57 ^{az*}	2.6 ± 0.11 ^{aw**}	2.5 ± 0.10 ^{ay**}	0.650	0.687	0.35 ± 0.13 ^{aw**}	0.25 ± 0.00 ^{aw****}
<i>Langra</i> wine	4.0 ± 0.15 ^{ax*}	4.1 ± 0.17 ^{ay*}	13.8 ± 0.78 ^{bw*}	13.4 ± 0.47 ^{az*}	2.7 ± 0.13 ^{aw**}	2.6 ± 0.09 ^{aw**}	0.634	0.750	0.12 ± 0.00 ^{ax****}	0.16 ± 0.00 ^{aw****}
<i>Dashehari</i> wine	3.6 ± 0.10 ^{ax*}	3.7 ± 0.10 ^{az**}	7.2 ± 0.27 ^{aw*}	6.1 ± 0.26 ^{aw*}	2.2 ± 0.28 ^{aw*}	2.1 ± 0.08 ^{aw**}	0.615	0.657	0.23 ± 0.00 ^{az****}	0.11 ± 0.00 ^{aw****}
<i>Banganapalli</i> wine	3.5 ± 0.10 ^{aw**}	3.8 ± 0.10 ^{aw****}	6.5 ± 0.23 ^{aw**}	5.2 ± 0.26 ^{aw**}	2.1 ± 0.15 ^{aw**}	2.0 ± 0.13 ^{aw**}	0.647	0.698	0.27 ± 0.06 ^{aw****}	0.14 ± 0.00 ^{aw****}
<i>Totapuri</i> wine	3.0 ± 0.10 ^{aw**}	3.0 ± 0.15 ^{aw****}	11.8 ± 0.19 ^{aw**}	11.2 ± 0.37 ^{ay*}	2.5 ± 0.22 ^{aw*}	2.5 ± 0.20 ^{aw*}	0.640	0.680	0.52 ± 0.00 ^{aw**}	0.45 ± 0.13 ^{aw**}

#As Tartaric acid; †As acetic acid; First superscript letter (a-d) shows the significant difference ($p < 0.05$) among a particular row, second superscript letter (w-z) shows the significant difference ($p < 0.05$) among a particular column for a specific attribute. Results are expressed as n = 3, SD ± 0.05, * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Table 3 Ethanol content in the wine produced from different mango varieties by fermentation using ISY (S1) and *Saccharomyces cerevisiae* MTCC 178 (S2) strains

Mango variety	Ethanol (% w/v)	
	S1 ^a	S2 ^b
<i>Alphonso</i>	8.8	9.0
<i>Langara</i>	9.7	9.5
<i>Dashehari</i>	11.5	12.0
<i>Banganapalli</i>	13.0	13.0
<i>Totapuri</i>	8.6	8.5

^aS1 represents the ISY

^bS2 represents the *Saccharomyces cerevisiae* MTCC 178 strain

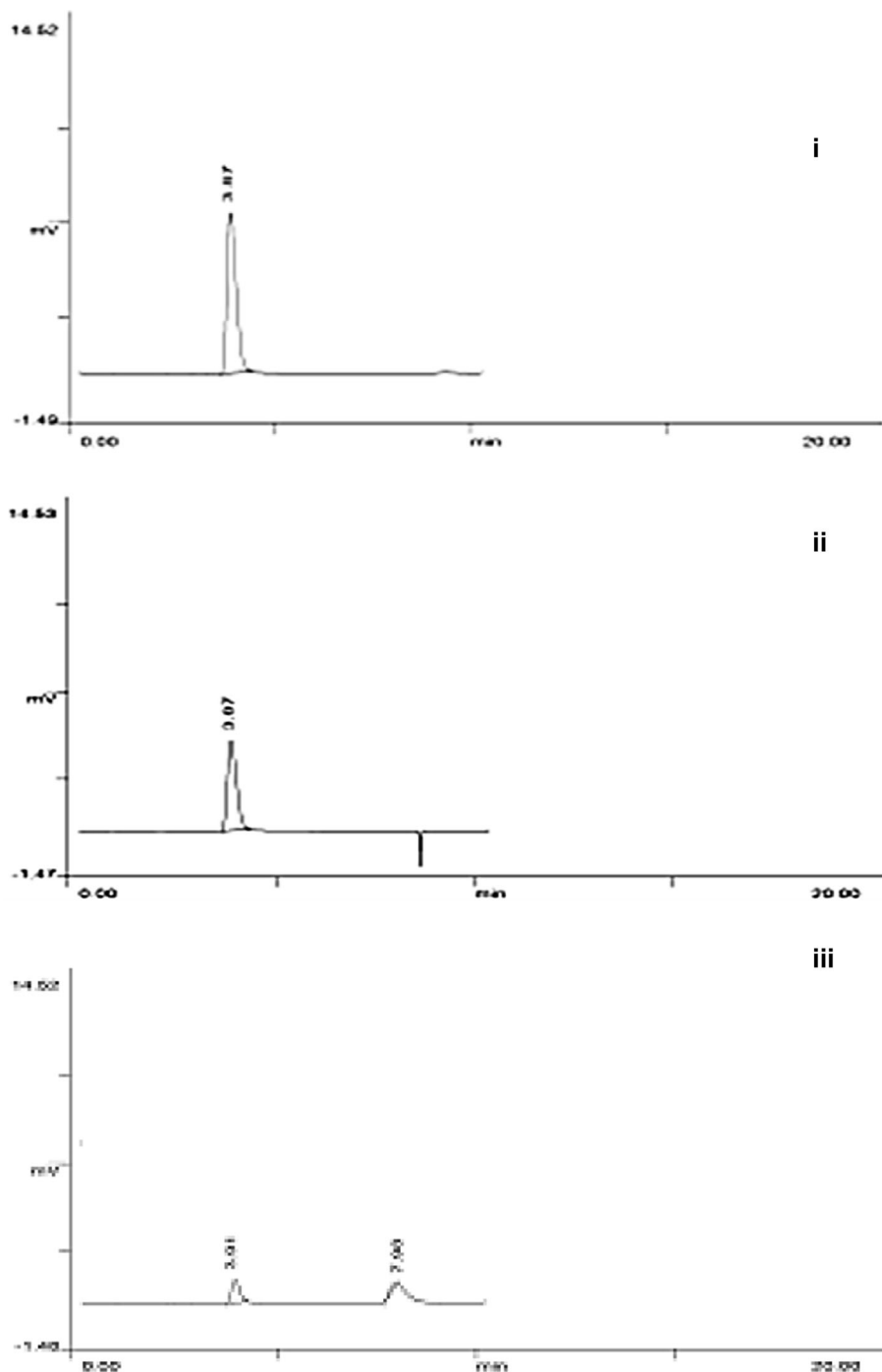
Ethanol estimation

The alcohol content of all the samples of mango wine were deduced by GC. Both the yeast culture showed insignificant ($p > 0.05$) variation in alcohol content (Table 3). The *Banganapalli* and *Dashehari* wine showed maximum ethanol content of 13 and 12% (v/v), respectively in S2 samples. Previously, the alcohol content in *Banganapalli* was reported to be 14.2% which is in close proximity to current investigation (Varakumar et al. 2011). However, *Totapuri* wine showed least ethanol content of 8.5% (v/v) (Table 3). There is no previous such reports on *Dashehari* wine and our investigation suggests that wine prepared from *Dashehari* mango varieties using S2 strain possessed higher alcohol content. Figure 2 A represents the GC profile of pure ethanol, *Dashehari* and *Totapuri* mango wine where, the peak obtained at retention time (RT) of 3.90 min represents ethanol. The GC profile of S2 treated *Totapuri* wine sample showed additional peak (RT-7.98 min) which represents isobutyl alcohol (Fig. 3iii).

HPLC analysis

HPLC analysis of S1 and S2 treated *Dashehari* and *Langra* wine was done for estimation of flavonoids and polyphenols. The HPLC profile of different wine showed a variety of flavonoids and polyphenolic compounds represented by their retention time (RT). The S1 treated *Dashehari* wine comprised gallic acid (4.4 min), Ethyl propionate (4.6 min), 2-furan methanol (4.99 min), methyl gallate (5.21 min), n-Butyl acetate (7.72 min), Protocatechuic acid (9.85 min), Ethyl valerate (10.21 min), p-Hydroxybenzoic acid (11.78 min) (Fig. 3i). Gallic acid (3,4,5-trihydroxybenzoic acid) is phytochemical considered as potential functional food ingredient having high antioxidant properties (Sethiya et al. 2014). Ethyl propionate, 2-furan methanol, methyl gallate, n-Butyl acetate, Ethyl valerate

Fig. 2 GC–MS chromatogram of the **i** standard ethanol, **ii** *Dashehari* and **iii** *Totapuri* mango wine. Nucon gas chromatograph instrument was used with 5% Carbowax 20 m glass column on Carbopack-B 80/120 mesh. 6 ft (2 m) 2 mmID1/4 mm, Detectot type: UV

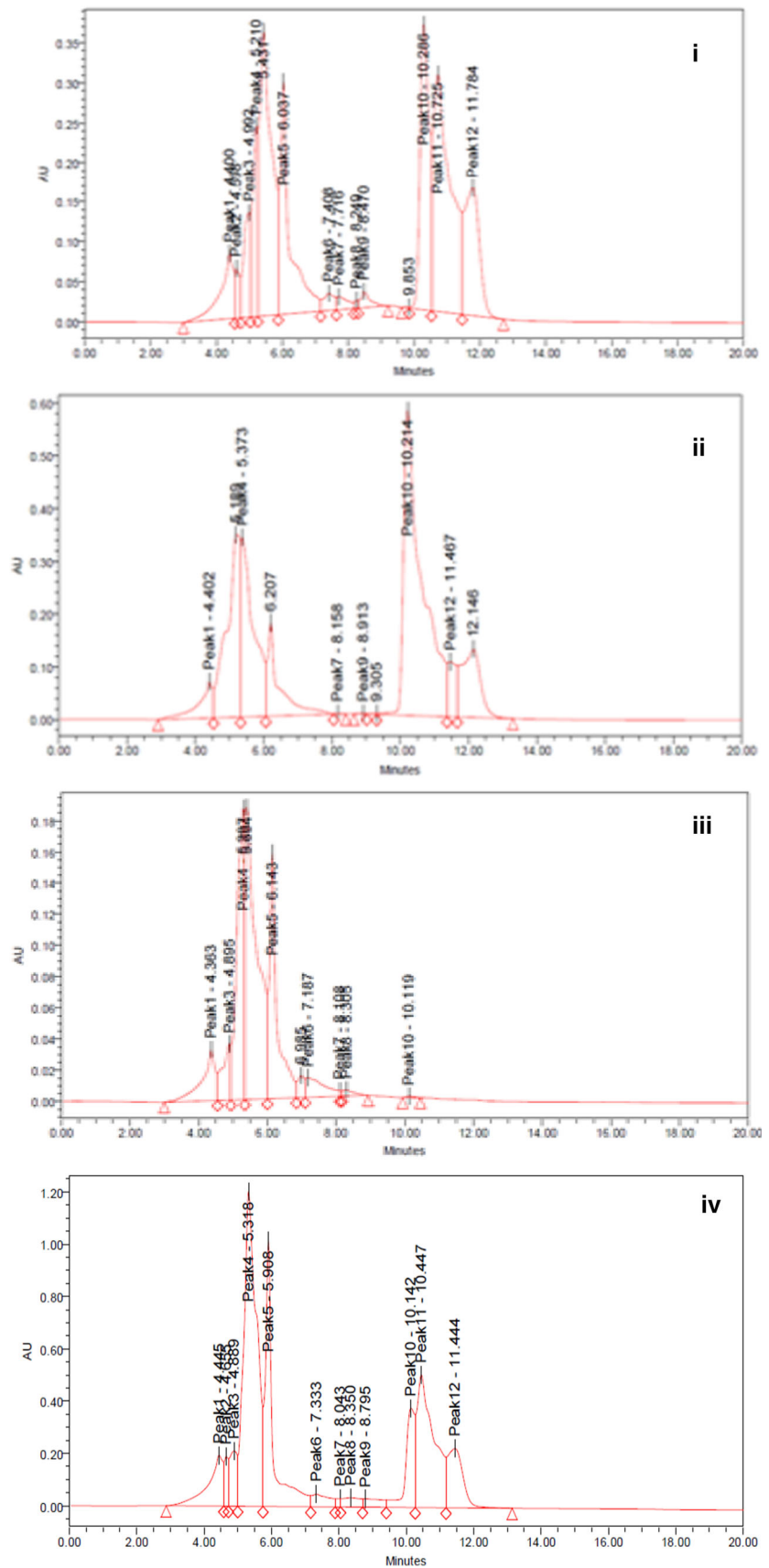


gives characteristic fruity odor, flavor and shows antimicrobial property. Protocatechuic acid (PCA) is phenolic compound which exhibit antioxidant, antimicrobial, anti-inflammatory, antidiabetic, anticancer, analgesic, hepatoprotective, neurological and nephro-protective activities (Kakkar and Bais 2014). p-Hydroxybenzoic acid shows antioxidant, antibacterial and antifungal properties. The phenolics present in fermented beverage can be extracted and can serve as additives in food pharma and cosmetic

industries as previously reported in the mango seed extracts mixed with palm stearin (Jahurul et al. 2014).

In contrary, S2 treated *Dashehari* wine comprised; gallic acid (4.4 min), Galloyl-A-type procyanidin (5.2 min), isopropyl alcohol (5.37 min), furanone (6.21 min), 2,2,6-Trimethyl-6-vinyltetrahydropyran (8.91 min), Ethyl valerate (10.21 min), β -Pinene (11.47 min) and Caffeoyl-quinic acid (12.15 min) (Fig. 3ii). Methyl gallate and Caffeoyl-quinic acid tannins derivatives have been found to have

Fig. 3 **i** HPLC chromatogram of S1 treated Dashehari wine showing individual flavonoid and polyphenol peak at specific retention time (RT). Peak 1 (4.4 min), Peak 2 (4.6 min), Peak 3 (4.99 min), Peak 4 (5.21 min), Peak 7 (7.72 min), Peak 9 (8.47 min), Peak 10 (10.21 min) and peak 12 (11.78 min). **ii** HPLC chromatogram of S 2 treated Dashehari wine showing individual flavonoid and polyphenol peak at specific retention time (RT). Peak 1 (4.4 min), Peak 2 (5.2 min), Peak 4 (5.37 min), Peak 5 (6.21 min), Peak 9 (8.91 min), Ethyl valerate (10.21 min), Peak 12 (11.47 min), Peak 13 (12.15 min). **iii** HPLC chromatogram of S 1 treated Langra wine showing individual flavonoid, sugar and polyphenol peak at specific retention time (RT). Peak 1 (4.4 min), Peak 6 (7.19 min), Peak 7 (8.10 min), Peak 8 (8.31 min), Peak 10 (10.12). **iv** HPLC chromatogram of S 2 treated Langra wine showing individual flavonoid, sugars and polyphenol peak at specific retention time (RT). Peak 1 (4.4 min), Peak 2 (4.67 min), Peak 3 (4.89 min), Peak 4 (5.32 min), Peak 5 (5.90 min), Peak 7 (8.04 min), Peak 8 (8.35 min), Peak 9 (8.8 min), Peak 10 (10.14 min), Peak 11 (10.44 min)



strong antioxidative properties (Okamura et al., 1993). Galloyl-A-type procyanidin is responsible for astringency when consumed (Naish et al., 1993). Caffeoyl-quinic acid is responsible for acidity and prevents microbial growth in wine. 2,2,6-Trimethyl-6-vinyltetrahydropyran also imparts the antioxidant properties by inhibiting the oxidation of hexanal. β -Pinene is monoterpene present in fruits and performs wide range of pharmacological studies such as antioxidants, antibiotic resistance modulation, anticoagulant, antitumour, antimicrobial, antimalarial, analgesic and anti-inflammatory activities (Salehi et al., 2019).

S1 treated *Langra* wine comprised; gallic acid (4.4 min), camphene (7.19 min), hexanal (8.10 min), isobutyl alcohol (8.31 min), Ethyl valerate (10.12) (Fig. 3iii). Camphene is terpenoid, which provides cytoprotective, antioxidant potential and prevents lungs inflammation (Tiwari and Kakkar, 2009).

Similarly, S2 treated *Langra* wine comprised; gallic acid (4.4 min), Ethyl propionate (4.67 min), galloyl glucose (4.89 min), isopropyl alcohol (5.32 min), isobutyl acetate (5.90 min), hexanal (8.04 min), isobutyl alcohol (8.35 min), 2,2,6-Trimethyl-6-vinyltetrahydropyran (8.8 min), citric acid (10.14 min), maltose (10.44 min) tartaric acid (11.44 min) (Fig. 3iv). The polyphenols and flavonoids attributed higher antioxidant properties in mango wine. Similar antioxidant and functional attributes were reported in pink guava products (Ooi et al. 2019).

Cost economics

In the present investigation, 580 mL of juice was extracted from 1 kg of *Dashehari* mangoes. To produce 1 L of wine, it requires 1305 mL of juice as after fermentation and evaporation losses. It clearly deduced that approximately 2.25 kg mangoes are required to produce 1 L wine, where the cost of raw material (mango) was Rs. 100/- as per the market price. It is also worth mentioning that about 40% of the raw material cost would be cost of processing including recovery. Hence, 1 L of mango wine will cost approximately, Rs. 250/-. However, the actual cost of production will be determined only after scale up.

Conclusion

As mangoes are grown widely as popular fruits, their use in wine production would go a long way in contributing considerably to the economy of not only Indian, but also international mango producers. The quality of wine is predominantly affected by chosen raw material and inoculum type. In the present study, the local mango variety of northern India (*Dashehari*) inoculated with *Saccharomyces cerevisiae* MTCC178, showed better

potential in wine making owing to its new physicochemical and functional attributes and alcohol content. The post-harvest loss of local variety during tropical climate is very high; this study targeted the utilization of abundances to minimize wastage. HPLC analysis of *Dashehari* wine revealed the presence of flavonoids and polyphenols, which can be beneficial in prevention of cancer, skin and cardiovascular diseases. Production can be further scaled up in high capacity reactors for its commercialization as a functional beverage.

Acknowledgements We are grateful to School of Biochemical Engineering, Indian Institute of Technology BHU, Varanasi for providing GC and HPLC facility.

Compliance with ethical standards

Conflict of interest There is no conflict of interest between the authors. The authors mutually agree to submit the manuscript in the Journal of Food Science and Technology.

References

- Akhtar S, Riaz M, Ahmad A, Nisar A (2010) Physico-chemical, microbiological and sensory stability of chemically preserved mango pulp. *Pak J Bot* 42:853–862
- Chilaka CA, Uchechukwu N, Obidiegwu JE, Akpor OB (2010) Evaluation of the efficiency of yeast isolates from palm wine in diverse fruit wine production. *Afr J Food Sci* 4(12):764–774
- Coulibely WH, N'guessan KF, Coulibaly I, Cot M, Rigou P, Djè KM (2016) Influence of freeze-dried yeast starter cultures on volatile compounds of tchapalo, a traditional sorghum beer from côte d'Ivoire. *Beverages* 2(35):33–90
- Dars AG, Hu K, Liu Q, Abbas A, Xie B, Sun Z (2019) Effect of thermo-sonication and ultra-high pressure on the quality and phenolic profile of mango juice. *Foods*. <https://doi.org/10.3390/foods8080298>
- Galanakis CM (2020) The food systems in the era of the coronavirus (covid-19) pandemic crisis. *Foods*. <https://doi.org/10.3390/foods9040523>
- Gloria MBA, Silva PS, Labanca RA (2011) Functional potential of tropical fruits with respect to free bioactive amines. *Food Res Int* 44:1264–1268
- Jahurul MHA, Zaidul ISM, Norulaini NAN, Sahena F, Kamaruzaman BY, Ghafoor K, Omar AKM (2014) Cocoa butter replacers from blends of mango seed fat extracted by supercritical carbon dioxide and palm stearin. *Food Res Int* 65:401–406
- Joshi V, Sharma S, Bhushan S (2005) Effect of method of preparation and cultivar on the quality of strawberry wine. *Acta Aliment* 34:339–353. <https://doi.org/10.1155/2014/952943>
- Kakkar S, Bais S (2014) A review on protocatechuic acid and its pharmacological potential. *ISRN Pharmacol*. <https://doi.org/10.1155/2014/952943>
- Kaleem M, Ahmad A, Ahmed Z, Shafiq H (2015) Therapeutic potential of flavonoids and their mechanism of action against microbial and viral infections: a review. *Food Res Int* 77(2):221–235
- Kumar Rajendra, Patel MP, Bose US, Tripathi SK (2001) Physico-chemical studies of some important mango varieties of Madhya Pradesh. *Crop Res* 22:38–42

- Maldonado-Celis ME, Yahia EM, Bedoya R, Landázuri P, Loango N, Aguillón J, Restrepo B, Ospina JCG (2019) Chemical composition of mango (*Mangifera indica* L.) fruit: nutritional and phytochemical compounds. *Front Plant Sci* 23:9. <https://doi.org/10.3389/fpls.2019.01073>
- Molina AM, Swiegers JH, Varela C, Pretorius IS, Agosin E (2007) Influence of wine fermentation temperature on the synthesis of yeast-derived volatile aroma compounds. *Appl Microbiol Biotechnol* 77:675–687
- Moreno AMV, Polo MC (2005) Winemaking biochemistry and microbiology: current knowledge and future trends. *Crit Rev Food Sci Nutr* 45:265–286
- Naish M, Clifford MN, Birch GG (1993) Sensory astringency of 5-O-caffeoylquinic acid, tannic acid and grape-seed tannin by a time-intensity procedure. *J Sci Food and Agricul* 61:57–64
- Okamura H, Mimura A, Yakou Y, Niwano M, Takahara Y (1993) Antioxidant activity of tannins and flavonoids in *Eucalyptus rostrata*. *Phytochem* 33:557–561
- Ooi CW, Nagarajan J, Krishnamurthy NP, Nagasunda RR, Raghunandan ME, Galanakis CM (2019) A facile water-induced complexation of lycopene and pectin from pink guava byproduct: Extraction, characterization and kinetic studies. *Food Chem* 296:47–55
- Palafox CH, Yahia E, González AG (2012) Identification and quantification of major phenolic compounds from mango (*Mangifera indica* cv. Ataulfo) fruit by HPLC–DAD–MS/MS–ESI and their individual contribution to the antioxidant activity during ripening. *Food Chem* 135:105–111
- Pierson JT, Curry MC, Shaw PN, Dietzgen RG, Gidley MJ, Roberts TSJ, Monteith GR (2015) Polyphenolic contents and the effects of methanol extracts from mango varieties on breast cancer cells. *Food Sci Biotechnol* 24:265–271
- Reddy L, Reddy O (2005) Production and characterization of wine from mango fruit (*Mangifera indica* L.). *World J Microbiol Biotechnol* 21:1345–1350
- Reddy LV, Reddy LP, Wee YJ, Reddy OVS (2011) Production and characterization of wine with sugarcane piece immobilized yeast biocatalyst. *Food Bioprocess Technol* 4:142–148
- Salehi B, Upadhyay S, Orhan IE, Jugran AK, Jayaweera SLD, Dias DA, Sharopov F, Taheri Y, Martins N, Baghalpour N, Cho WC, Sharifi-Rad J (2019) Therapeutic potential of α - and β -pinene: a miracle gift of nature. *Biomolecules* 9(11):738
- Sethiya NK, Trivedi A, Mishra S (2014) The total antioxidant content and radical scavenging investigation on 17 phytochemical from dietary plant sources used globally as functional food. *Biomed Prev Nutr* 4(3):439–444
- Tiwari M, Kakkar P (2009) Plant derived antioxidants: geraniol and camphene protect rat alveolar macrophages against t-BHP induced oxidative stress. *Toxicol In Vitro* 23(2):295–301
- Varakumar S, Kumar YS, Reddy OVS (2011) Carotenoid composition of mango (*Mangifera indica* L.) wine and its antioxidant activity. *J Food Bioch* 35:1538–1547
- Versari A, Ricc KJ, Olejar GP, Parpinello PA, Kilmartin A (2015) Application of Fourier transform infrared (FTIR) spectroscopy in the characterization of tannins. *Appl Spect Rev* 50(5):407–442
- WHO Director-General’s Opening Remarks at the Media Briefing on COVID-19—11 March 2020. Available online: <https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-mediabriefing-on-covid-19—11-march-2020>. Accessed 13 April 2020
- Winner L (2004) Introduction to biostatistics. University of Florida, Gainesville, pp 1–20

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.