Development of a cost-effective, palatable and shelf-stable blended beverage of pummelo (*Citrus grandis* Linn.)

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Development of a cost-effective, palatable and shelf-stable blended beverage of pummelo (*Citrus grandis* Linn.).

Abstract — Introduction. Natural beverages face strong competition from synthetic drinks in the open market. Creation of diversity in natural products is a key strategy to withstand this competition. Pummelo (*Citrus grandis* Linn.) is one such potential fruit which could be exploited on a commercial scale if processed properly. The bitterness of pummelo juice is a serious handicap in its utilization. The present study aimed at preparation of a cost-effective, palatable blended beverage of pummelo. **Materials and methods**. To overcome this problem, pummelo was blended with mango ginger and kokum juice in the ratio of [65:30:5] for the preparation of syrup. The product was stored for 120 days in ambient conditions of storage and analyzed for changes in its physicochemical constituents. **Results and discussion**. Total soluble solids and total sugar increased during storage, while titratable acidity and ascorbic acid content decreased slightly during storage. Organoleptically, the best recipe was 25% juice, 70 °Brix total soluble solids and 1.5% acidity with a score of 6.3 out of 7.0 for overall acceptability. Mango ginger juice suppressed the bitter aftertaste of pummelo juice and imparted its characteristic taste and flavor to the product. The product was shelf-stable and had important medicinal constituents in it. The [total revenue / total cost] ratio of the product was 2.90.

India / *Citrus grandis* / *Curcuma amada* / *Garcinia indica* / beverages / fruit juices / fruit syrups / profitability / flavor / quality

Développement d'une boisson mixte à base de pamplemousse (*Citrus grandis* Linn.) rentable, agréable au goût et apte à la conservation.

Résumé — Introduction. Les boissons naturelles doivent faire face à une forte concurrence des boissons synthétiques sur le marché libre. La création de diversité parmi les produits naturels serait la stratégie-clé pour résister à cette concurrence. Le pamplemousse (*Citrus grandis* Linn.) est l'un des fruits potentiels qui pourraient être exploités à l'échelle commerciale s'ils sont traités correctement. L'amertume du jus de pamplemousse est un handicap sérieux pour son utilisation. Notre étude a cherché à préparer une boisson à base de pamplemousse qui serait à la fois rentable et agréable de goût. **Matériel et méthodes**. Pour surmonter le problème de l'amertume, du jus de pamplemousse a été mélangé à du jus de curcuma-gingembre-mangue (*Curcuma amada)* et de kokum (*Garcinia indica*) dans un rapport de [65:30:5] pour la préparation de sirop. Le produit a été stocké pendant 120 jours en conditions ambiantes et analysé quant aux changements des caractéristiques physico-chimiques des constituants. **Résultats et discussion**. La matière sèche soluble et les sucres totaux ont augmenté au cours du stockage alors que, pendant la même période, l'acidité titrable et la teneur en acide ascorbique ont légèrement diminué. D'un point de vue gustatif, le meilleur mélange a été de 25 % de jus et 65 % de sirop à 70 °brix de matière sèche soluble et 1,5 % d'acidité avec une note d'acceptabilité globale de 6,3 sur 7,0. Le jus de curcuma-gingembre-mangue a supprimé l'arrière-goût amer du jus de pamplemousse et a donné son goût caractéristique et sa saveur aux produits. Le produit a été stable et a conservé d'importants composants médicinaux. Le rapport [revenus totaux / coût total] du produit a été de 2,90.

Inde / *Citrus grandis* / *Curcuma amada* / *Garcinia indica* / boisson / jus de fruits / sirop de fruits / rentabilité / flaveur / qualité

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1. Introduction

Pummelo (*Citrus grandis* Linn.) is the largest fruit of the genus *Citrus*. It is a monoembryonic species of the citrus group. The fruits are, generally, (20 to 25) cm in diameter, weighing up to 3.21 kg [1]. The flesh of pummelo is firm with crisp capillary membranes and juice sacs. The color of the flesh may be white or pinkish red. Juice recovery from the fruits is around 50–55%. Total soluble solids (TSS) content of the juice varies between (7 and 11) °Brix. Pummelo is a fairly good source of ascorbic acid, which is found in the range of 30–43 mg·100 g^{-1} of the edible portion [2]. Antioxidant content and free radical scavenging ability of red pummelo juice are greater than those of white pummelos as it contains a higher amount of carotenoids and phenolics [3]. At optimum maturity, pummelo contains about 10% total sugar, 2.8% citric acid, 20 mg ascorbic acid·100 mg^{-1}, 38 mg calcium·100 g^{-1}, 52 mg phosphorus·100 g^{-1} and 0.6 g fiber·100 g^{-1} [4]. Fruits contain several bioactive constituents, such as carotenoids, limonoids, flavonones (naringin) and vitamin B complex, which play the role of nutraceuticals. They also provide fiber and pectin, which are known to reduce the risk of heart attacks if taken daily in the diet [5]. The Geographical Indication Registry of the Government of India has conferred 'Devanahalli Pink Fleshed', an ecotype of pummelo, with the status of 'Geographical Indication' owing to its peculiar taste. In the present study, this ecotype was used for the preparation of a refreshing blended syrup.

Mango ginger (*Curcuma amada*) is one of the important medicinal members of the family *Zingiberaceae*. Botanically, it is close to ginger but its rhizomes possess a raw mango-like odor, hence the name 'mango ginger'. The rhizome pieces are (3 to 10) cm long and (1 to 3.5) cm broad, laterally compressed and pale brown in color. Rhizomes contain essential oil (1.1%), resin, sugar, gum, starch, albuminoids and organic acid. It is carminative, cooling, aromatic, stomachic (tones the stomach, improving its function and increasing appetite), and astringent in nature. In the *Ayurveda* system of medicine, it has been described as "*Sarvakandoovinaashini*" [6].

Kokum (*Garcinia indica*) is a crop of the Western *Ghats* of India. In recent years, it has gained popularity due to its anti-obesity activity owing to hydroxy citric acid (HCA) content in its rind. The rind is also a rich source of anthocyanin, an antioxidant which could be used as a natural food color [7]. Fruits are spherical in shape, and purple-colored, with a rough rind enclosing 5 to 8 seeds covered with mucilaginous pulp. The fruit is cooling, cholagogue, demulcent, emollient and antiscorbutic [6].

In spite of being a 'Geographical Indication' crop, 'Devanahalli Pink Fleshed' pummelo has largely been underutilized due to its slightly bitter aftertaste. Bitterness sets in after juice extraction due to conversion of limonoate ring-A lactone (a tasteless precursor of limonin) to limonin in ruptured tissues [3]. Hence, it is a challenging task to prepare food products from pummelo with acceptable sensory quality. Although sophisticated technologies involving the use of enzymes, resinous adsorbents or high pressure processing, etc., offer solutions for reducing bitterness in pummelo juice, it is imperative to devise some feasible solutions which could be employed on a home scale or in cottage-level processing. Keeping these factors in mind, our present investigation was undertaken to standardize the recipe for cost-effective preparation of an appetizing blended beverage from pummelo.

2. Materials and methods

2.1. Extraction of juice and preparation of juice blend

For the extraction of juice from pummelo fruits, the fruits were peeled using stainless steel knives and the albedo portion was thoroughly removed to minimize the bitterness in the product. The juicy sacs were then separated from the segments and blended in a mixer. The juice obtained was filtered with the help of muslin cloth. Juice from mango ginger rhizomes was obtained by blending peeled rhizome pieces with water

Table I.
Changes in total soluble solids TSS (°Brix) and titratable acidity (%) during storage of a syrup of pummelo juice blended with mango ginger and kokum with a ratio of [65:30:5].

Treatments			TSS (°Brix)					Titratable acidity (%)				
Juice (%)	Sugar syrup (%)	°Brix of sugar syrup	Fresh	30 d	60 d	90 d	120 d	Fresh	30 d	60 d	90 d	120 d
25	75	65	65	65.5	66.2	66.8	67.3	1.50	1.46	1.42	1.39	1.35
		70	70	70.4	70.9	71.5	72.1	1.50	1.45	1.41	1.39	1.35
30	70	65	65	65.6	66.4	66.9	67.4	1.50	1.47	1.44	1.40	1.37
		70	70	70.5	71.1	71.7	72.2	1.50	1.48	1.45	1.41	1.38
	F-test		NS	NS	NS	NS	NS	NS	NS	NS	NS	*
	SEm±		–	–	–	–	–	–	–	–	–	0.016
	CD at 5%		–	–	–	–	–	–	–	–	–	0.035

* Significant at the 5% level; each value is a mean of four replications. NS: not significant.

in the ratio of 1:2 (w/v). The fleshy pulp from kokum fruits was separated from the rind and a known quantity of rind was blended with an equal amount of water to obtain the juice. Pummelo, mango ginger and kokum juices were thereafter blended in the ratio of [65:30:5].

2.2. Preparation of blended syrup

Sugar syrup of (65 and 70) °Brix strength, respectively, was prepared by dissolving sugar in warm water and the blended juice was added to two sets of these solutions in the ratio of [25:75] and [30:70]. Total soluble solids of the product were adjusted using sugar as required, and a uniform titratable acidity (1% citric acid) was maintained in all the treatments. Sodium benzoate was added as a preservative to the product as per the Fruit Products Order (1955) specifications (600 $mg \cdot L^{-1}$). Then, the final product was filtered and poured into pre-sterilized glass bottles of 200 mL capacity each. The bottles were corked, using a pedal-operated crown corking machine, and this was followed by pasteurization for 30 min at 70 °C by the holding method. The products were later stored at room temperature.

The product was analyzed for different chemical parameters initially, then at 30-day intervals throughout the storage period of 120 days. Total soluble solids (TSS) were determined using a digital refractometer and expressed in °Brix. Titratable acidity was calculated in terms of percent citric acid present in the product. Total sugars in the beverage were determined using Lane and Eynon's method (1927). Ascorbic acid content was determined using a spectrophotometer. The product was subjected to sensory analysis just after preparation and at the end of storage. For the sensory analysis, a panel of ten members was selected based on their previous experience in judgment of fruit beverages. The panel was asked to do the evaluation for the product's color, flavor, taste, aftertaste and overall acceptability on a seven-point hedonic scale. The experiment was laid out using a Completely Randomized Design (CRD) with four replications in each treatment. The cost of production was calculated for the best recipe.

3. Results

The total soluble solids content of the beverage increased during storage (*table I*). The maximum increment (2.4 °Brix) was noticed in the treatment (30% juice and

Table II.
Changes in total sugar (%) and ascorbic acid (mg·100 mL^{-1}) content during storage of a syrup of pummelo juice blended with mango ginger and kokum with a ratio of [65:30:5].

Treatments			Total sugars (%)					Ascorbic acid (mg·100 mL^{-1})				
Juice (%)	Sugar syrup (%)	°Brix of sugar syrup	Fresh	30 d	60 d	90 d	120 d	Fresh	30 d	60 d	90 d	120 d
25	75	65	45.12	45.14	45.21	45.27	45.35	6.50	6.12	5.51	4.92	4.23
		70	49.23	49.27	49.36	49.48	49.60	6.43	6.01	5.43	4.96	4.36
30	70	65	46.33	46.35	46.43	46.52	46.66	7.62	7.21	6.63	6.12	5.66
		70	50.42	50.45	50.53	50.64	50.75	7.71	7.22	6.75	6.13	5.59
F-test			Not significant					Not significant	*	*	Not significant	*
SEm±			–	–	–	–	–	–	0.029	0.012	–	0.017
CD at 5%			–	–	–	–	–	–	0.063	0.026	–	0.037

* Significant at the 5% level; each value is a mean of four replications.

Table III.
Mean sensory scores of a syrup of pummelo juice blended with mango ginger and kokum with a ratio of [65:30:5] (pre- and post-storage evaluations).

Treatments			Color		Flavor		Taste		Aftertaste		Overall acceptability	
Juice (%)	Sugar syrup (%)	°Brix of sugar syrup	Fresh	120 d	Fresh	120 d	Fresh	120 d	Fresh	120 d	Fresh	120 d
25	75	65	6.9	6.2	6.4	5.5	6.4	5.5	5.1	4.6	6.2	5.5
		70	6.9	6.3	6.6	5.7	6.5	5.6	5.2	4.8	6.3	5.6
30	70	65	7.0	6.5	6.5	5.7	6.2	5.3	4.6	4.1	6.1	5.4
		70	7.0	6.6	6.4	5.6	6.3	5.4	4.7	4.2	6.1	5.5

Each value represents the mean scores given by a ten-member panel, on the basis of a 7-point hedonic scale.

syrup of 65 °Brix). During the 120 days of storage, acidity showed a gradual decreasing trend (*table I*). The maximum reduction (0.11%) in titratable acidity was observed in the treatments (25% juice and syrup of 65 °Brix) and (25% juice and syrup of 70 °Brix).

The total sugar content of the blended syrup increased during storage (*table II*). Variations were significant at various juice and TSS levels. However, the interaction effect was not significant throughout the period of storage. The maximum increase in total sugar content (0.37%) was observed in the treatment (25% juice and syrup of 70 °Brix). The ascorbic acid content of the blended syrup decreased during storage (*table II*). Juice concentrations had a direct relation with the ascorbic acid content throughout the storage period but the interaction effect was significant only at (30, 60 and 120) days of storage. The maximum reduction (2.27 mg·100 mL^{-1}) in ascorbic acid content was noted in the treatment (25% juice and syrup of 65 °Brix).

The blended syrup was analyzed for various sensory parameters by organoleptic evaluation (*table III*).

Table IV.
Cost of production [in Rupees (Rs.)] of 4 L of pummelo juice blended with mango ginger and kokum with a ratio of [65:30:5] (25% juice and syrup of 70 °Brix).

1) Ingredients	Quantity (g)	Amount (Rs.)
Pummelo	2500	50.00
Mango ginger	300	21.00
Kokum	50	1.50
Sugar	6000	108.00
Sodium benzoate	2.4	2.50
Citric acid	60	5.10

2) Containers	Quantity	Amount (Rs.)
Bottles (200 mL each) + corks	20	50.00

3) Additional charge	Working days	Amount (Rs.)
Man power	0.5	30.00

4) Miscellaneous charges (electricity charges, water charges, depreciation cost of the machine, fuel charges, price of muslin cloth used for filtration) : Rs. 8.00

Total cost (ingredients + containers + man power + miscellaneous)	Total revenue (20 bottles × Rs. 40[1])	Net revenue (total revenue – total cost)	[Total revenue / total cost] ratio
Rs. 276.10 for 4 L	Rs. 800	Rs. 523.90	2.90

[1] Standard price fixed for the syrups by the Pilot Processing Plant of Univ. Agric. Sci., Bengaluru, Karnataka, India.

There were no drastic differences among samples with respect to color scores. However, the highest score (7.0) was recorded in the case of the treatments (30% juice and syrup of 65 °Brix) and (30% juice and syrup of 70 °Brix) during the initial evaluation. During the final evaluation, the score was maximum for the treatment (30% juice and syrup of 70 °Brix).

The maximum scores (6.6 and 5.7) for flavor were recorded in the case of the treatment (25% juice and syrup of 70 °Brix) in the pre- and post-storage evaluations, respectively. Scores were lower when juice content was higher in the product.

The maximum scores (5.2 and 4.8) for aftertaste were recorded for the treatment (25% juice and syrup of 70 °Brix), both before and after storage, respectively.

The results of the initial evaluation showed that the highest overall acceptability score (6.3) was given to the treatment (25% juice and syrup of 70 °Brix). The post-storage results were also supportive of the maximum overall acceptability (score 5.6) of the treatment (25% juice and syrup of 70 °Brix). However, differences were very slight among the treatments.

Cost economics for the best treatment (25% juice and syrup of 70°Brix) showed

that the product had a sufficiently high [total revenue / total cost] ratio of 2.90 to be taken up as a cottage and small-scale enterprise (*table IV*).

4. Discussion

An increasing trend was observed in the total soluble solids (TSS) content of mango ginger and kokum blended pummelo syrup during storage. This increase might be due to hydrolysis of polysaccharides such as starch and pectic substances into simpler substances which contributed to increased TSS content. Similar observations were recorded by Thakur and Barwal in squash of kiwifruit [8] and Nath *et al.* in ginger blended kinnow mandarin squash [9].

The acidity of the prepared product gradually declined during storage. This decrease in acidity might be due to acid hydrolysis of polysaccharides and non-reducing sugars to their simpler components where acid is utilized for converting them to hexose sugars or complexes in the presence of metal ions. The degree of reduction in acidity is dependent on the concentration of sugar and is a general phenomenon during storage of beverages in the presence of sugars [10]. The declining trend might also be due to chemical interaction between the chemical constituents of the juice induced by temperature influencing enzymatic action [11]. Reduction in acidity during storage of beverages was observed by Khurdia in a blended mango beverage [12], Lashmi *et al.* in flavored tamarind ready-to-serve beverages [13] and Nidhi *et al.* in a ready-to-serve bael-guava beverage [14].

The total sugar content of mango ginger and kokum blended pummelo syrup increased slightly during storage. It could be attributed to the acid hydrolysis of polysaccharides which resulted in increase in soluble sugar content. The results were in line with the findings in a muskmelon ready-to-serve beverage [15], in a pear-apricot beverage [16], in a papaya-guava blended ready-to-serve beverage [17] and in a mango-lemongrass beverage [18].

Blended pummelo syrup showed a declining trend in ascorbic acid content throughout the storage period. Decrease in ascorbic acid content might be due to the effect of storage temperature and catalytic activity of fructose [19]. Thermal degradation during processing and subsequent oxidation and light reaction were the other possible causes of reduction in ascorbic acid content [20]. Since ascorbic acid content of the beverage is directly dependent on the blended juice used for its preparation, comparatively higher ascorbic acid content was observed at the end of the storage period in the case of samples with 30% juice than those containing 25% only. Analogous observations for decline in ascorbic acid content were recorded in orange juice by Goyle and Ojha [21] and in bael-guava RTS by Nidhi *et al.* [14].

The color scores of the product were influenced by the amount of blended juice (due to increased kokum juice concentration) used in the product and total soluble solids content. Treatments involving higher juice percentage were given higher scores for color. Color retention was also greater in the treatments involving a higher percentage of blended juice.

Flavor scores had a negative correlation with increased juice percentage but scores improved a little when the TSS level increased. This might be due to the fact that increased sweetness positively interacted with the strong flavor of mango ginger. Hence, flavor scores were a composite interaction of blended juice and total soluble solids level.

The trend of taste scores was also in line with that of flavor scores. As the unpleasant aftertaste was mainly imparted by the bitterness of the pummelo juice and pungency of mango ginger juice, increased juice percentage evidently decreased the scores of the samples and with the passage of time scores gradually decreased due to the prominent ginger taste. It might be due to the fact that, during storage, the acidity of the product decreased and the ginger flavor became dominant.

In the freshly prepared products, the bitterness of pummelo was absent as the pungency of ginger suppressed it but, after

120 days of storage, the products became slightly unpleasant as the ginger flavor became dominant. The trend was the same in all four products. However, scores were better when the juice percentage was lower in the products. Even at the same juice level, the level of total soluble solids directly influenced the scores as the samples with higher total soluble solids scored better.

Overall acceptability scores were a composite of scores for other characters because panelists were asked to keep in mind all other sensory parameters while scoring for this parameter. Hence, the treatment involving lower juice content and the highest TSS content (25% juice and syrup of 70°Brix) was adjudged the best among all the treatments.

5. Conclusion

Thus, it was possible to prepare palatable syrup from pummelo juice with the least investment to overcome the inherent bitterness of pummelo juice and, in addition, improve its medicinal value. Also, the results proved the shelf-stable nature of the product as there were slight differences in the product quality before and after storage, which did not have any negative impact on the acceptability of the product. The [total revenue / total cost] ratio of blended pummelo syrup was 2.90 and, due to its highly concentrated nature, it could be diluted up to 5 times before its consumption. These qualities suitably justify its potential for commercialization.

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Elaboración de una bebida mixta a base de pomelo (*Citrus grandis* Linn.) rentable, de sabor agradable y apta a conservarse.

Resumen — Introducción. Las bebidas naturales deben hacer frente a una fuerte competencia de bebidas sintéticas en el mercado libre. Crear más diversidad entre los productos naturales sería la estrategia perfecta para resistir a esta competencia. El pomelo (*Citrus grandis* Linn.) es uno de los frutos potenciales que podrían explotarse a escala comercial, si se trataran correctamente. El amargor del zumo de pomelo es un serio obstáculo para su uso. Nuestro estudio pretendió preparar una bebida a base de pomelo que fuera a la vez rentable y de sabor agradable. **Material y métodos**. Para contrarrestar el problema del amargor, se mezcló zumo de pomelo con zumo de cúrcuma-jengibre-mango (*Curcuma amada)* y de kokum (*Garcinia indica*) en una relación de [65:30:5] para la preparación del jugo. El producto se almacenó durante 120 días en condiciones ambientales y se analizó en cuanto a los cambios de las características físico-químicas de los constituyentes. **Resultados y discusión**. La materia seca soluble y los azúcares totales aumentaron a lo largo del almacenamiento, mientras que, durante el mismo periodo, la acidez valorable y el contenido en ácido ascórbico disminuyeron ligeramente. Desde un punto de vista gustativo, la mejor mezcla fue la de un 25 % de zumo y de un 75 % de jugo a 70 °Brix de materia seca soluble y de un 1,5 % de acidez, presentando una nota de aceptabilidad general de 6,3 de 7,0. El zumo de cúrcuma-jengibre-mango suprimió el regusto amargo del zumo de pomelo y dio su sabor característico y su aroma a los productos. El producto fue estable y conservó importantes componentes medicinales. La relación [ingresos totales / coste total] del producto fue de 2,90.

India / *Citrus grandis* / *Curcuma amada* / *Garcinia indica* / bebidas / jugo de frutas / jarabe de frutas / rentabilidad / sabor / calidad