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PHYSICO-CHEMICAL CHARACTERIZATION AND PRODUCT DEVELOPMENT FROM LOCAL CITRUS GERMPLASMS AVAILABLE IN THE SOUTH WESTERN REGION OF BANGLADESH

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ABSTRACT

The experiment was carried out to study the physico-chemical characteristics of 20 selected citrus fruits germplasm of South Western region of Bangladesh during July 2010 to January 2012. There was significant variation among the germplasms in relation to fruit characteristics and organolaptic evaluation. Better performance was found in germplasm No. 20 in respect of total fruit weight, weight of seed and skin thickness of fruits. Germplasm No.1 showed better performance in respect of percentage of edible portion and germplasm No. 6 in respect of percentage of non edible portion. The total soluble solids found higher in germplasm No. 20 (12.23 %) and titratable acidity in germplasm No. 16 (49.33 %). Vitamin C and carotenoids found maximum in germplasm No. 20 (442.70 mg/100g). Germplasm No. 4 and 12 was better in respect of anthocyanin (0.10 mg/100gm) and flavonoids (0.19 gm) content of fruit pulp. Considering desired fruit characteristics germplasam No. 20 (pummelo) was found better. Citrus fruits' squash was successfully prepared by using 60 g sugar containing treatment consisting 50-80 g of sugar with 10 g variation of sugar in three treatments without changing other ingredient. Citrus fruits jelly was successfully prepared by using 300 g sugar containing treatment consisting 250-350 g of sugar with 50 g variation of sugar in three treatments without changing other ingredient. Citrus fruits jarok was successfully prepared by using 55 g salt containing treatment consisting 50-60 g of salt with 5 g variation of salt in three treatments without changing other ingredient.

Keywords: Physico-chemical characteristics, germplasm, Bangladesh, citrus, fruits

INTRODUCTION

Citrus fruits (*Citrus spp.)* is one of the most popular fruits in Bangladesh. Citrus is a common term and genus (*Citrus*) of flowering plants in the family Rutaceae. The generic name came from the Greek word 'cedar'. There are two beliefs regarding the origin of this generic name : one group of people believe that the Jews used the fruits of *C. medica* during the Feast of the Tabernacles in exchange of a cedar cone (**Kimball, 1999**) where as others think that it was because of the similarity in the aroma of citrus leaves and fruit with that of cedar (**Spiegel and Eliezer, 1996**). Citrus is believed to have originated in the part of Southeast Asia bordered by Northeastern India, Myanmar (Burma) and the Yunnan province of China. Citrus fruit has been cultivated in an ever-widening area since ancient times; the most well known examples are the oranges, pummelo, lemons and limes (**Andrews, 1961**).

Citrus fruits have several cultivated species such as *Citrus aurantifolia* (Key lime), *Citrus maxima* (Pomelo), *Citrus medica* (Citron) and *Citrus reticulata* (Mandarin orange). The fruit also has several important hybrides viz *Citrus aurantium* (Bitter orange), *Citrus latifolia* (Persian lime), *Citrus limon* (Lemon), *Citrus limonia* (Rangpur Lemon), *Citrus paradisi* (Grapefruit), *Citrus sinensis* (Sweet orange) and *Citrus tangerina* (Tangerine) (**Nicolosi *et al.*, 2000**). The genetic origin of the lemon, however, was reported to be hybrid between sour orange and citron (**Morton, 1987**). Oranges can be grown, outdoors in warmer climates, and indoors in cooler climates (**Sackman and Cazaux, 2005**).

Lemons are grown all over Bangladesh, though their production is concentrated in Sylhet, Chittagong and the Chittagong Hill Tracts; cultivated in homestead as well as in orchard, mainly from grafts and cuttings. Fruits are ovate to elliptical or oblong with thick skin; become pale yellow on ripening. Lemon fruits are sour and juicy containing high vitamin C. They are consumed fresh for juice and used in making pickles and beverages. Some local varieties are seedless such as, Elachi lebu, Pati lebu, Kaliganj lebu, Shasni lebu, etc. Lemons are available year-round with a peak during the summer months. Recently Bangladesh Agricultural Research Institute (BARI) released one variety named BARI Lebu-1. It has Elachi (cardamom) flavour. The fruit is large, oblong, about 260g weight with rough skin. It is juicy (26%) and acidic, contains some seeds. An average yield is 62 fruits per plant. Bangladesh Agricultural Research Institute (BARI) has also released two varieties, namely BARI Lebu-2 and BARI Lebu-3. BARI Lebu-2 is round, medium, about 81 g, sour and juicy (33%). BARI Lebu-3 is round, small, about 55 g, less sour and highly juicy (38%) (**Banglapedia, 2006**).

Citrus fruits are consumed not only because of their taste but also because of the beneficial effects they have on the health. There are various health benefits associated with the consumption of citrus fruits, as they are low in fat, free of cholesterol and sodium. Citrus fruits are rich in vitamin C content, acid content and are good sources of minerals, carbohydrates, fibers, etc. They also contain essential nutrients like calcium, copper, folate, potassium, magnesium, niacin and vitamin B6 required for the proper functioning of the body. Citrus fruits have several medicinal and nutritive properties, which help in treating or fighting against several diseases. Citrus fruits like lemons may help in reducing the pain caused due to bee stings. Some types of citrus fruits may help in reducing the risk of cancers and heart diseases. Orange, which is a rich source of vitamin C, can prevent scurvy. Some types of citrus fruits are sources of essential oils, which are used in perfumes and other cosmetic products. Citrus fruits don't have any negative effects on the health (**Araujo *et al.*, 2003**). The zest of a citrus fruit, typically lemon or an orange, can also be soaked in water in a coffee filter, and drunk. In 2007, citrus was the secret ingredient on Iron Chef America (**Meyer, 1908**). Before the development of fermentation-based processes, lemons were the primary commercial source of citric acid (**Tucker *et al.*, 1996**).

Literature reviews reveal that researchers in Bangladesh context have under taken a few research work relating to physio-chemical studies of different local citrus fruits (spp.) accessions and no research work has been undertaken in the south western region, though physio-chemical studies on different papaya and banana fruits have been carried out **M. S. Akhter, *et al.* (2012), Akhter S. *et al.* (2012)**. With this circumstance the present study was undertaken to study the physico-chemical characteristics of local citrus fruits germplasm available in the south western region of Bangladesh. There is a scope to select superior citrus fruits (spp.) germplasm from field survey and collection of same to mitigate the fruit and nutritional shortage for the scarcity period. Important products of citrus fruits are not available in the local markets except some imported from abroad. So product development from citrus fruits are essential to make it available to all the

people especially the rural poor to mitigate their malnutrition problem, to some extent.
Hence, the present study was under taken to fulfill the following objectives: to study the pattern of physico-chemical properties of some selected citrus fruits and develop the product(s) from citrus fruits.

MATERIAL AND METHODS

The fruits were collected randomly from the South Western region of Bangladesh viz. Khulna, Jessore, Bagerhat and Satkhira district and some were from the germplasm center of the Agrotechnology Discipline, Khulna University, Bangladesh. Three fruits were collected from each germplasm. Fruit characteristics were studied in The Horticulture Laboratory of the Agrotechnology Discipline, Khulna University, Bangladesh to determine the physico-chemical characteristics of citrus fruits (*Citrus spp.*) and development of products from them.

Expt. No. 1 Study of Physico-chemical Characteristics of Citrus Germplasms

Experimental Design

The experiment was laid out in a completely randomized design (CRD). After collection of mature fruits those were kept in refrigerator or at ambient temperature for the study of physico-chemical characteristics. About 20 germplasms of 5 different species of citrus fruits were included as the experimental materials. List of citrus fruits with English, scientific, local name and collection area has been presented in appendix I.

Physical Characteristics

Physical characteristics like weight, size, shape, skin color, skin thickness, weight of rind & non-edible portion, weight of pulp, seed & edible portion, percentage of edible & non-edible were determined as described by M. S. Akhter, *et al*. (2012), **Akhter S. *et al*. (2012).**

Chemical Characteristics

The methods for the estimation of pH, total soluble solids, titratable acidity and ascorbic acid of fruit pulp were followed as described by **Saini *et al*. (2006), Mazumder and Mujumder (2003) and Ranaganna (1979)**. The data were analyzed on fresh weight basis.

Expt. No. 2 Product Development from Citrus Fruits

Experimental Design

To develop product from the desired fruits, the experiment was laid out in Complete Randomized Design (CRD) using three formulations with three replications. The formulations of the experiment have been shown in table 1, 2 and 3. The experiments were conducted in The Horticulture Laboratory of the Agrotechnology Discipline, Khulna University, Bangladesh.

Equipments

Digital balance, blender machine, chula(oven), saucepan, measuring cylinder, refractometer, dish, spoon, knives and bottle.

Chemicals

Citrus fruits, their juice, sugar, sodium benzoate, pectin, distil water, vinegar and salt.

Method of Analyzing the Product

Sensory evaluation of citrus fruit products were done following the technique adopted by **Razzaque (2007)** and **Kabir (2006)**. Duncan's Multiple Range Test (DMRT) was applied to compare the treatment. An expert panelists consisting of 10 members ensuring participation of equal representative from both sex male and female judged the processed products. All the judges were made conversant with the factors governing the quality of the products. The process products were served to each judge who independently examined the product quality and assigned score for the characteristics-(i) Colour, (ii) Taste, (iii) Flavour and (iv) Texture. The relative importance of each factor was expressed numerically.

Lime Squash

Lime squash was prepared as described by Akhter S. *et al*. (2012).. Formulations of the recipes were shown in the Table 1.

Table 1 Formulations for lime squash

Sl.	Ingredients	T_1	T_2	T_3
01	Lime juice (ml)	150	150	150
02	Sugar (g)	60	70	80
03	Sodium benzoate (g)	0.36	0.36	0.36
04	Distil water (ml)	75	75	75

Now sealed the bottles with lid and pasteurized for 20 minutes at 85^0C. The bottles were cleaned, labeled and stored in a dry place away from light for further investigation. Citrus pulp preservation was performed in accordance with **Razzaque, 2007**.

Lime Jelly

Jelly from lime was prepared with some modifications as described by M. S. Akhter, *et al*. (2012), Akhter S. *et al*. (2012).

Table 2 Formulations for lime jelly

Sl.	Ingredients	T_1	T_2	T_3
01	Lime juice (ml)	150	150	150
02	Sugar (g)	250	300	350
03	Pectin (g)	3	3	3
04	Sodium benzoate (g)	0.36	0.36	0.36
05	Distil water (ml)	150	150	150

Jarok of Lime (kaguci lebu)

Well-matured limes were selected. The medium size fruits were collected carefully and avoided the less juicy fruit. The skin was removed so that green layer cleaned completely keeping the fruit. Then it was washed reasonably with fresh water and mixed with salt. This lime dried on sunlight for two days. This salt mixed lime poured into bottle. Then vinegar was poured into this lime filled bottle so that lime drowned into vinegar. Lid of bottled was closed and kept on sunlight for some days. Formulations of the recipe were shown in the Table 3. Now sealed the bottles with lid and pasteurized for 20 minutes at 85^0C.

Table 3 Formulations for Jarok of lime (kaguci lebu)

Sl.	Ingredients	T_1	T_2	T_3
01	Lime	10	10	10
02	Salt (g)	50	55	60
03	Vinegar (ml)	150	150	150

The bottles were cleaned, labeled and preserved in a dry place away from light for further investigation as followed by **Kabir, 2006**.

Statistical Analysis

The collected data including for organoleptic evaluation were statistically analyzed by Analysis of Variance method. Duncan's Multiple Range Test (DMRT) was used to compare the means of different parameters.

RESULTS AND DISCUSSION

Expt. No. 1 Study of Physico-chemical Characteristics of Citrus Germplasm

Physical Characteristics of Citrus Fruits

Data on physical characteristics of citrus fruits are presented in Table 4. The physical characteristics of citrus fruits are described based on quantitative and qualitative characteristics.

Quantitative Characters

Weight of Individual Fruit

The fruit weight was significantly varied among the 20 germplasm. The germplasm No. 20 gave the maximum fruit weight (896.70 g) followed by germplasm No. 5 (156.00 g), No. 11 (131.60 g), No. 16 (118.50 g) and No. 10 (106.20 g); while it was minimum (21.89 g) in germplasm No. 4 (Table 4). Average fruit weight of citrus fruits was found 114.86 g. **Hossain (1985)** cited that in Bangladesh weight of this fruit varied from 396g to 1418g.

Length of Fruit

The longest fruit (9.50 cm) was found in germplasm No. 17 which was statistically similar to germplasm No. 16 (9.03 cm) and shortest fruit (3.63cm) was measured from germplasm No 4 (Table 4). The findings do not coincide with **Hossain (1985)** who found the length of mature fruit from 12.1cm to18.2 cm and width 11.1 cm to18.6 cm.

Width of Fruit

The broadest fruit (6.53 cm) was found in germplasm No. 5 which was statistically similar to germplasm No. 11 (6.33 cm) flowed by germplasm No. 10 (5.87 cm) which was statistically similar to germplasm No 16 (5.77 cm), No. 19 (5.73 cm) and No 1 (5.53 cm) . The narrowest fruit (3.23 cm) was measured from germplasm No.9 which was statistically similar to germplasm No. 4 (3.33 cm) (Table 4).

Seed Weight (per fruit)

Significant difference was found among the 20 germplasm in respect of seed weight. Germplasm No. 20 had the highest seed weight (24.51 g) followed by germplasm No. 2 (4.80 g) and No. 7 (4.33 g), while the lowest seed weight (0.22 g) was found in germplasm No. 3 which was statistically similar to germplasm No. 4 (0.28 g), No. 11 (0.65 g) and No. 9 (0.81 g).

Skin Thickness

The thickest skin (1.12 cm) was found in germplasm No. 20 followed by germplasm No. 6 (0.62 cm), No. 11 (0.59 cm) and No. 3 (0.41 cm) and the thinnest skin (0.19 cm) was noted from germplasm No.10. The average skin thickness was observed 0.35 cm.

Weight of Non-edible Portion

Significant variation was observed among the 20 germplasm in relation to the non-edible portion. The maximum weight of non-edible portion (317.7 g) was found in germplasm No. 20 followed by the minimum weight (6.57 g) was measured from germplasm No.4 which was statistically similar to germplasm No. 3 (11.67 g) and No.9 (11.73 g) (Table 4). The weight of non-edible portion, on an average, was found 42.14 g.

Weight of Edible Portion

The maximum weight of edible portion (557.8 g) was found in germplasm No.20 followed by germplasm No. 5 (113.5 g), No.16 (88.49 g) which was statistically similar to germplasm No. 1 (79.46 gm) and No. 11 (76.52 g). The minimum weight of edible portion (15.04 g) was noted from germplasm No.4 (Table 4). The average weight of edible portion was obtained 70.77 g.

Weight Non-edible Portion (%)

Significant variation was observed among the 20 germplasm in relation to the non-edible portion. The maximum weight of non-edible portion (74.52 %) was found in germplasm No. 6 followed by germplasm No. 17 (54.89 %) which was statistically similar to germplasm No. 2 (53.30 %) and No. 18 (51.74 %), and the minimum weight (17.77 %) was measured from germplasm No. 1 which was statistically similar to germplasm No. 5 (20.73 %) (Table 4).

Weight of Edible Portion (%)

Germplasm No. 1 possessed the maximum weight of edible portion (82.23 %) which was statistically similar to germplasm No. 14 (73.36 %) , No. 16 (73.21 %), and No. 5 (72.37 %)and the minimum weight of edible portion (25.48 %) was noted from germplasm No.6 (Table 4). This variation may be due to climatic, edaphic and also varietal differences.

Qualitative Characters

Shape of Fruit

There was remarkable variable among the 20 germplasm in respect of fruit shape. Most of the fruit were regular (cylindrical, round, oblate and oval) in shape but some of them where irregular in shape. It was found that most of the fruits were oblate to oval shaped, while the others were round shaped. **Morton, J. 1987** mentioned the lemon is oval yellow fruit.

Table 4 Physical Characteristic of Citrus Fruits

Citrus Species	Germplasm no.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Seed weight (g)	Skin thickness (cm)	Non edible portion (g)	Edible portion (g)	Total non edible portion (g)	Non edible portion (%)	Edible portion (%)
	3	33.73 no	4.50 i	3.80 f	0.22 i	0.41 c	11.67 ij	21.83 fgh	11.89 hi	35.60 fgh	64.40 bcd
	4	21.89 o	3.63 j	3.33 g	0.28 i	0.21 n	6.567 j	15.04 h	6.85 i	33.07 gh	66.93 bcd
	6	79.18 gh	6.23 c	5.03 d	4.30 c	0.62 b	54.62 b	20.26 gh	58.92 b	74.52 **a**	25.48 g
	8	57.05 jk	6.20 cd	4.13 ef	2.17 e	0.30 j	22.26 g	32.62 efgh	24.42 f	42.60 cd	57.40 def
Lime	**12**	39.85 mn	4.97 ghi	3.77 f	0.93 gh	0.21 m	16.50 gh	22.41 fgh	17.44 gh	44.03 c	55.97 def
	13	48.52 klm	5.57 cdefg	3.90 f	1.32 f	0.21 n	15.80 hi	31.40 efgh	17.12 gh	35.30 fgh	64.70 bcd
	16	118.50 d	9.03 **a**	5.77 b	1.40 f	0.30 j	41.95 d	88.49 c	43.35 cd	36.81 efgh	73.21 ab
	17	86.87 fg	9.50 **a**	4.20 ef	0.00 i	0.40 e	47.60 c	42.61 de	47.60 c	54.89 b	48.61 f
	1	96.46 ef	5.77 cdef	5.53 bc	3.93 d	0.21 n	13.07 i	79.46 c	17.00 gh	17.77 i	82.23 **a**
	7	73.15 hi	5.33 efgh	5.00 d	4.33 c	0.33 f	28.29 f	40.53 def	32.62 e	44.69 c	55.31 def
Lemon	**9**	28.98 no	4.77 hi	3.23 g	0.81 gh	0.19 o	11.73 ij	16.44 h	12.54 hi	43.25 cd	56.75 def
	14	52.80 jkl	5.97 cde	4.43 e	1.02 g	0.18 p	19.43 gh	39.01 defg	20.45 fg	38.67 def	73.36 ab
	15	40.75 lmn	5.13 fghi	4.03 ef	1.92 e	0.33 g	16.29 ghi	22.54 fgh	18.21 gh	44.71 c	55.29 def
	18	63.46 ij	8.03 b	4.07 ef	0.00 i	0.22 l	32.79 ef	30.67 efgh	32.79 e	51.74 b	48.26 f
	19	92.53 f	5.07 fghi	5.73 b	2.00 e	0.31 i	35.25 e	55.27 d	37.26 e	40.18 cdef	59.82 cdef
Orange	**2**	73.07 hi	5.27 efghi	5.13 cd	4.80 b	0.31 h	34.06 ef	36.54 efg	38.86 de	53.30 b	49.80 ef
	10	106.20 e	5.43 defgh	5.87 b	2.14 e	0.18 p	31.56 ef	72.49 c	33.70 e	31.71 h	68.29 bcd
Malta	**5**	156.00 b	6.33 c	6.53 **a**	1.31 f	0.25 k	31.22 ef	113.5 b	32.53 e	20.73 i	72.37 abc
	11	131.60 c	6.17 cd	6.33 **a**	0.65 h	0.58 c	54.44 b	76.52 c	55.09 b	41.82 cde	58.18 def
Pummelo	**20**	896.70 **a**	5.10 fghi	5.40 bcd	24.51 **a**	1.11 **a**	317.70 **a**	557.80 **a**	342.20 **a**	38.16 defg	62.21bcde
	Average	114.86	5.90	5.56	2.90	0.35	24.14	70.77	45.04	41.18	59.93
	Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	C.V %	6.35	7.04	4.67	5.84	3.41	8.14	14.40	7.81	6.89	11.49

N.B. In a column figures having similar letters do not differ significantly whereas figures having dissimilar letters differ significantly as per DMRT.

Colour of Skin

Variation was also found in case of type of skin colour among the 20 germplasm. Various skin colour was found in different fruits viz. deep green, deep yellow, greenish yellow, yellowish green, greenish, yellowish and whitish green.

Chemical Characters of Fruits

pH of Fruit Pulp

The highest pH of fruit pulp was found in germplasm No.5 (5.70) followed by germplasm No. 1 (5.21), No. 10 (3.84), No. 20 (3.44) and No.11 (3.30) (Table 5).

The results correlate with the findings of **Morton (1987)** and **Crowell (1999)** who reported the pH of 2 to 3 and 2.5-3, respectively.

Total Soluble Solids (Brix %) of Fruit Pulp

The highest total soluble solids of fruit pulp were observed from germplasm No.20 (12.23 %) followed by germplasm No. 11 (9.90 %), No. 9 (7.00 %), No. 5 (6.93 %) and No. 7 (6.80 %). The least amount of total soluble solids of fruit pulp was observed from germplasm No. 4 (4.77 %) which was statistically similar to germplasm No. 14 (4.87 %), No. 1 (4.90 %), No. 17 (5.13 %), No. 19 (5.20 %) and No. 16 (5.23 %). (Table 5. Similar results in respect of total soluble solids (TSS) content were also reported by **Satter and Mahmud (1991)**.

Titratable Acidity of Fruit Pulp

The germplasm No. 16 (49.33 %) contained the maximum amount of titratable acid followed by germplasm No. 17 (46.67 %), No. 19 (44.05 %), No. 15 (42.67 %), and No.8 (34.93 %) (Table 5). **Satter and Mahmud (1991)** mentioned that juice sample contain 1.05 % to1.13 % of titratable acidity (TA) and **Sinclair (1972)** said that titratable acidity (TA) may constitute 8 % to15 % and 8 % to 23%.

Vitamin C (ascorbic acid) Content of Fruit Pulp

The highest vitamin C content fruit pulp was found in Germplasm No. 20 (442.7 mg/100 g) and the lowest amount of ascorbic acid content was observed from germplasm No. 13 (15.17 mg) which was statistically similar to germplasm No. 16 (15.89 mg), No. 9 (16.61 mg), No. 10 (17.33 mg) and No. 4 (19.50 mg) (Table 5). Similar resu vitamin C content 53 mg were also reported by **Gulsen and Roose (2001)**. Food Value Per 100 g of Edible Portion, ascorbic acid contain Fruit (fresh, peeled) 53 mg, Juice (fresh) 46 mg, Juice (canned, unsweetened) 42 mg, Juice (frozen, unsweetened) 44 mg, Lemonade (concentrate, frozen) 30 mg, Peel (raw) 129 mg supported by **Morton (1987)** .

Carotenoids of Fruit Pulp

Significant variation was observed among the 20 germplasm in respect of carotinoids content. Fruits of germplasm number 20 found to contain the highest amount of carotenoids (15.92 mg/100 g) whereas germplasm No. 3 showed the lowest amount of carotenoids (0.68 mg/100 g) proceeded by germplasm No. 17 (1.44 mg/100 g) which was statistically similar to germplasm No. 6 (1.51 mg/100 g) (Table 5). The total carotenoid contents ranged from 2.42 $\mu g \cdot g^{-1}$ in the Washington variety to 15.8 $\mu g \cdot g^{-1}$ in the Valencia variety **Giuffrida *et al.* (2010)**. Among the varieties studied in our work, only the Sanguinello variety showed a total carotenoid content similar to the Valencia variety (14.59 $\mu g \cdot g^{-1}$).

Anthocyanin of Fruit Pulp

The anthocyanin showed significant variation among the 20 germplasm. The maximum amount of anthocyanine content was found in germplasm No. 4 (0.10 mg/100 g) followed by germplasm No. 13 (0.10 mg/100 g) and No. 18 (0.05 mg/100 g). The minimum amount of titratable acid content was recorded from germplasm No.7 (0.02 mg/100 g) proceeded by germplasm No. 1 (0.02 mg/100 g) which was statistically similar to germplasm No. 2 (0.03 mg/100 g) and No. 3(0.03 mg/100 g). (Table 5).

Flavonoids of Fruit Pulp

The difference of flavonoids was significant among the 20 germplasm. The highest flavonoids of fruit pulp were observed from germplasm No. 12 (0.19 g) followed by germplasm No. 10 (0.15 g), No. 8 (0.13 g) and No. 13 (0.12 g). The least amount of total soluble solids of fruit pulp was observed from germplasm No. 2 (0.03 g) (Table 5). According to Peterson *et al.* (2006) for lemons, total flavanoids contents (summed means) were 26 mg/100 g and for limes 17 mg/100 g.

Table 5 Chemical Characteristics of Citrus Fruits

Citrus Species	Germplasm no.	p^H	TSS (%)	T-acidity (%)	Vitamin C (mg/100g)	Carotinoids (mg/100g)	Anthocyanine (mg/100g)	Flavonoids (g/100g)
Lime	**3**	2.73 h	5.57 fg	24.35 h	20.94 hi	0.68 j	0.03 i	0.08 gh
	4	2.37 k	4.77 h	20.09 j	19.50 ij	3.13 f	0.10 **a**	0.05 ij
	6	2.88 g	6.00 ef	19.97 j	41.17 f	1.51 i	0.05 cd	0.12 de
	8	2.02 q	6.50 cde	34.93 e	25.28 gh	0.00 k	0.02 ef	0.13 c
	12	2.07 opq	6.10 ef	21.50 i	25.28 gh	4.54 d	0.04 fgh	0.19 **a**
	13	2.28 kl	6.00 ef	28.33 g	15.17 j	6.20 c	0.09 b	0.12 d
	16	2.05 pq	5.23 gh	49.33 **a**	15.89 ij	2.40 g	0.05 cd	0.07 h
	17	2.35 k	5.13 gh	46.67 b	21.67 hi	1.44 i	0.03 h	0.05 ij
	1	5.21 b	4.90 h	0.88 n	49.33 e	2.13 h	0.02 i	0.05 i
	7	2.51 j	6.80 cd	31.68 f	26.00 gh	0.00 k	0.02 j	0.11 ef
Lemon	**9**	2.63 i	7.00 c	28.53 g	16.61 ij	0.00 k	0.04 fgh	0.08 g
	14	2.15 mno	4.87 h	28.53 g	21.67 hi	2.43 g	0.04 efg	0.10 f
	15	2.12 nop	6.03 ef	42.67 d	46.22 ef	0.00 k	0.04 de	0.08 g
	18	2.24 lm	5.67 fg	29.01 g	27.45 g	3.72 e	0.05 c	0.05 ij
	19	2.17 mn	5.20 gh	44.05 c	43.33 f	0.00 k	0.05 cd	0.11 de
Orange	**2**	3.10 f	6.43 de	20.62 ij	54.89 d	4.55 d	0.03 i	0.03 k
	10	3.84 c	6.77 cd	5.29 m	17.33 ij	0.00 k	0.04 gh	0.15 b
Malta	**5**	5.70 **a**	6.93 cd	0.70 n	86.67 b	3.72 e	0.03 h	0.04 j
	11	3.30 e	9.90 b	10.20 k	65.00 c	12.12 b	0.05 cd	0.12 de
Pummelo	**20**	3.44 d	12.23 **a**	7.93 l	442.70 **a**	15.92 **a**	0.04 fgh	0.11 ef
	Average	2.86	6.40	24.76	54.11	3.23	0.04	0.09
	Level of Significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	C.V %	1.79	4.66	2.97	5.76	4.48	2.02	2.02

N.B. In a column figures having similar letters do not differ significantly whereas figures having dissimilar letters differ significantly as per DMRT.

Expt. No. 2 Product Development from Citrus Fruits

Squash of Citrus Fruits

In respect of overall consideration of colour, taste, flavour and texture of squash treatment No. 2 (6.30) showed better performance among the 3 treatment (Table 6).

Table 6 Major component of citrus fruits' squash

Treatment	Colour	Taste	Flavour	Texture	Overall acceptability
T_1	4.60 b	3.90 b	4.70 b	5.50 ab	4.68 b
T_2	6.40 a	6.20 a	6.40 a	6.20 a	6.30 a
T_3	4.30 b	4.20 b	4.00 b	4.30 b	4.20 b

Note: T_1 = Lime juice 150 g, sugar 60 g, sodium benzoate 0.36 g and distil water 75 ml., T_2 = Sugar 70 g without changing other ingredients, T_3 = Sugar 80 g without changing other ingredients. In a column figures having similar letters do not differ significantly whereas figures having dissimilar letters differ significantly as per DMRT.

Jelly of Citrus Fruits

In overall consideration (colour, taste, flavour and texture of jelly), treatment No. 2 (6.38) showed better performance among the 3 treatment (Table 7).

Table 7 Major component of citrus fruits' jelly

Treatment	Colour	Taste	Flavour	Texture	Overall acceptability
T_1	5.20 a	4.44 b	4.50 b	5.00 b	4.79 b
T_2	6.40 a	6.40 a	6.10 a	6.60 a	6.38 a
T_3	3.50 b	3.70 b	3.20 b	3.50 c	3.48 c

Note: T_1 = Lime juice 150 g, sugar 250 g, pectin 2 g, sodium benzoate 0.24 g and distil water 100 ml., T_2 = Sugar 300 g without changing other ingredients, T_3 = Sugar 350 g without changing other ingredients. In a column figures having similar letters do not differ significantly whereas figures having dissimilar letters differ significantly as per DMRT.

Jarok of Citrus Fruits

Treatment No. 2 (6.30) showed better performance among the 3 treatment (Table 8) in context of colour, taste, flavour and texture consideration.

Table 8 Major component of citrus fruits jarok

Treatment	Colour	Taste	Flavour	Texture	Overall acceptability
T_1	4.80 b	4.00 b	4.80 b	4.20 b	4.45 b
T_2	6.40 a	6.20 a	6.40 a	6.20 a	6.30 a
T_3	3.50 b	4.00 b	3.50 b	4.30 b	3.83 c

Note: T_1 = Number of lime 10, salt 50 g, vinegar 160 ml., T_2 = Salt 55 g without changing other ingredients, T_3 = Salt 60 g without changing other ingredients. In a column figures having similar letters do not differ significantly whereas figures having dissimilar letters differ significantly as per DMRT.

CONCLUSION

The criteria for the selection of the citrus fruits germplasms may be fruit weight, edible portion, Vitamin C, Total soluble solid (TSS), pH and titratable acidity of the fruit. Most of the characters were found superior in germplasm No. 20, 5 and 16. Further trial is needed on other characters of the germplasm like reducing sugar, non reducing sugar, phenol, antioxidant etc. for the selection of the above mentioned germplasm as variety. If the production of citrus fruits derived food stuff increases, it will help to fulfill the fruit demand and reduce malnutrition problem of rural people of the country. All citrus fruits are not available year round in the country. So it is possible to preserve these fruits by development of products like squash, jelly and jarok to meet the nutritional requirement, to some extent, of people of a country like Bangladesh.

REFERENCES

AKHTER, S. – MANNAN, A. – GHOSH, A. 2012. Physico-chemical characterization and product development from papaya (*Carica papaya*) germplasm available in south western region of Bangladesh. *IRJALS*, 1(2), 49 – 62.

AKHTER, M. S. , - MANNAN, M. A., - LA-ELA, *ET AL*. 2012. Physico-chemical characterization and product development from banana germplasms available in south western region of Bangladesh. *IRJALS,* 1(1).

ANDREWS, A.C. 1961. Acclimatization of citrus fruits in the mediterranean region. In *Agricultural History*, vol. 35, 1961, no.1, p. 35-46. http://www.jstor.org/stable/3740992

ARAUJO, D.E. – FREITAS, E. – QUEIROZ, D.E., - PAGANUCCI, L. AND - MACHADO, M. A. 2003. Citrus : organisms, diversity & evolution. 3(1), 55-62. doi:10.1078/1439-6092-00058.

CROWELL, P.L. 1999. Prevention and therapy of cancer by dietary monoterpenes. In *The Journal of Nutrition*., 129(3), 775–778.

GIUFFRIDA, D. – DUGO, P. – SALVO, A. – SAITTA, M. – DUGO, G. 2010. Free carotenoids and carotenoids ester composition in native orange juices of different varieties. In *Fruits* (Journal), www.fruits-journal.org, 65(5), 277–284.

GULSEN, O. – ROOSE, M. L. 2001. Lemons: diversity and relationships with selected citrus genotypes as measured with nuclear genome markers. In *Journal of the American Society of Horticultural Science*, 126, 309–317.

KABIR, P. S. 2006. Ranna Khadya Pushti. First edit. Prime publications, 16/1, Eskaton Garden Road, Dhaka, Bangladesh, 360 p.

KIMBALL, D. A. 1999. Citrus processing: a complete guide . In *Springer*, 17, p. 9.

MAZUMDER, B. C. – MAJUMDER, K. 2003. Methods on physico- chemical analysis of fruits. In *Botanical Sciences*, 15, 151-162.

MEYER, F. N. 1908. Lemons: diversity and relationships with selected citrus genotypes as measured with nuclear genome markers. In *Journal of the American Society of Horticultural Science,* 126, 309–317.

MORTON, J. F. 1987. Avocado Lemon : Fruits of Warm Climates. Fifth edit. Pub Miami. Florida, 91–112 p.

MORTON, J. F. 1987. Lemon : Fruits of Warm Climates. Third edit. Pub. Miami. Florida, 160–168 p.

NICOLOSI, E. – DENG, Z. N. – GENTILE, A. – LA MALFA, S. – CONTINELLA, G. – TRIBULATO, E. 2000. Citrus phylogeny and genetic origin of important species as investigated by molecular markers. In *Theoretical and Applied Genetics*, 100(8), 1155-1166.

RANGANNA, S. 1979. Lab Manual Analysis of Fruits and Vegetables Products. First edit. Tata Mc Graw Hill Publishng Company Ltd., New Delhi, 140-144 p.

RAZZAQUE, MD. A. 2007. Khaddo Prokriajatkoron. Second edit. Text Book Division, Bangla Academy, Dhaka, Bangladesh, 174-177 p.

S. ISLAM. 2006. Banglapedia : National Encyclopedia of Banglaesh. First edit. Banglapedia Trust, Asiatic Society of Bangladesh**,** 102-109 p. ISBN 984-32-0576-6. http://www.banglapedia.org/httpdocs/english/copiright.html.

SACKMAN, – CAZAUX, D. 2005. Orange Empire : California and the Fruits of Eden, Multidimensional History of Citrus Industry in California. Second edit. University of California Press, 1-10 p.

SAINI, R. S. – SHARMA, K. D. – DHANKHAR, O. P. – KAUSHIK, R. A. 2006. Laboratory Manual of Analytical Techniques in Horticulture. First edit., Dev Publishers & Distributors, New Delhi, India, 105-112 p. ISBN 13: 9788177540819.

SATTER, A. – MAHMUD, S. 1991. Fatty acids of indigenous resources for possible industrial application: part xix. fatty acid composition of citrus grandis and citrus reticulata var. Sangtra. In *Pakistan Journal of Scientific and Industrial Research*, 34(6), 238-239.

SINCLAIR, W.B. 1972. The Grapefruit : it's Composition, Physiology and Product. First edit., University of California, Division of Agricultural Sciences, Berkely, USA, 1972, 365 p. ISBN-13: 978-0-931876-11-0.

SPIEGEL-ROY, P. – ELIEZER E. G.1996. Biology of Citrus. Second edit. Cambridge University Press, 4 p. ISBN 978-0-521-33321-4.

TUCKER, K. – SELHUB, J. – WILSON, P. – ROSENBERG, I. 1996. Dietary pattern relates to plasma folate and homocysteine concentrations in the framing ham heart study. In *Journal of Nutrition*, 126, 3025-3031.

Appendix I

Table A1 List of citrus fruits

Germplasm No	English Name	Scientific Name	Local Name	Area of Collection
1	Lime	*Citrus aurantifolia*	Sorboti lebu 1	Germplasam center of Agrotechnology Discipline, Khulna University, Bangladesh
3			Kaguci lebu 1	
4			Kamkot	
6			Sate lebu 1	
7			Sorboti lebu 2	Khulna, Bangladesh
8			Elaci lebu 1	
12			Kaguci lebu 2	
13			Kaguci lebu 3	
16			Sate lebu 2	Satkhira, Bangladesh
17			Kalombag lebu	
9	Lemon	*Citrus lemon*	Pati lebu 1	Bagerhat, Bangladesh
14			Pati lebu 2	Khulna, Bangladesh
15			Pati lebu 3	
18			Pati lebu 4	Jessore, Bangladesh
19			Gora lebu	
2	Orange	*Citrus sinensis*	Kamala 1	Khulna, Bangladesh
10			Kamala 2	
5	Malta	*Citrus reticulata*	Malta 1	
11			Malta 2	
20	Pummelo	*Citrus grandis*	Batabi lebu or Zambura	