20-46

FINAL REPORT OF MAJOR RESEARCH PROJECT

TITLE: Antioxidant capacity of fresh and variously processed fruits and vegetables of Assam

Submitted to

The Secretary

UGC
New Delhi

Submitted by

Dr. Charu Lata Mahanta
Professor & Principal Investigator
Department of Food Engineering and Technology
Tezpur University
Napaam- 784 028, Tezpur

PR. PI.
7/6/2013

SUMMARY OF WORK

The application of various cooking and other temperature treatments generally alters the native state of any fruits or vegetables. Heat led to softening and destruction of tissue structures in the cell matrix hence changes the organoleptic as well as nutritional and phytochemical properties. The present study found that cooking can make the polyphenols and antioxidants of cooked food quite different from that of uncooked food. This is probably due to variety of effects like destruction, release and transformation of the phytochemicals. From the present study it was observed that the extraction efficiency of the solvents differed for different vegetables depending on the diversity of the phenolic compounds present. However, methanol, water and acetone have good extractability properties. Cooking enhanced the antioxidant activity of the selected vegetables than the raw forms in most of the cases. Overall, steaming was the most preferred method for cooking. But in case of cooked banana blossom, a decrease in flavonoid content was observed. Overall, antioxidant activity of the minimal processed samples decreased with the increase in duration of storage.

The selected fruits contain considerably good phenolic content and high antioxidant activities except in *Bhimkal* and pineapple where the content is lower compared to the rest of selected fruits. The pasteurization treatment had negative effect on the TPC, TFC and antioxidant activities in pineapple (*Ananas comosus*), watermelon (*Citrullus lanatus*), *pani jamun* (*Syzygium samarangense*) and *litchi* (*Litchi chinensis*) whereas carambola or star fruit (*Averrhoa carambola*) and *black jamun (Syzygium cumini)* showed an increasing trend. Overall, *carambola* fresh juice has better antioxidant properties which are further enhanced on pasteurization. Watermelon has low levels of antioxidant capacities. During spray drying a significant difference in phytochemical content between the untreated and spray dried fruit juice was observed. Application of cabinet or tray drying as well vacuum and freeze drying had both positive and negative effects on the phytochemical properties of the selected seven fruits. In case of storage study of fruits, the phytochemical content and activity decreased in all the samples regardless of the storage temperature conditions.

INTRODUCTION

Fruits and vegetables are very rich sources of phytochemicals with antioxidant activity. These phytochemicals provide protection against harmful free radicals that are being produced in the human body because of the various metabolic processes. These free radicals are often responsible for inducing chronic diseases, such as cardiovascular diseases, cancer, diabetes, Alzheimer disease and age-related functional decline in health (Knekt et al., 2002; Liu et al., 2000). Commonly, fruits are consumed mostly in raw form and vegetables are cooked before consumption by simple boiling or microwave cooking. These cooking methods involve the application of temperature which brings about a number of changes in physical characteristics and chemical composition of vegetables (Suknwant et al., 1992). However, cooking brings about a number of physical and chemical changes in the vegetables (Rehman et al., 2003). These changes could be both beneficial and detrimental depending on the extent and type of treatment conditions. Variety of effects like destruction, release and structural transformation of the phytochemicals takes place during the cooking process. Cooking treatments like boiling, microwaving (Zhang & Hamazau, 2004), baking, frying and griddling lead to changes in texture and nutritional properties of the vegetables. Rodriguez-Amaya (1999) reported that cooking softens the cell walls which lead to increase in the extraction of carotenoids. However, other studies have reported that cooking can also lead to loss in essential vitamins and antioxidants mostly water soluble and heat labile compounds. The extent of loss is dependent on the type of cooking treatment (Lin & Chang, 2005).

The estimation and determination of phenolic compounds is mainly influenced by type of phenolic compounds present, solvent polarity, extraction method and conditions (Prior & Cao, 1999). The phenolic compounds exhibit different solubility pattern depending on the polarity of the phenolic acids present in them. Different solvents like methanol, ethanol, acetone, water and ethyl acetate can be used for phenolic compound extraction (Naczk & Shahidi, 2004). During the study of the effect of temperature on the polyphenols and antioxidant activity of the concerned vegetables, the type of solvent used for extraction of polyphenols and its polarity are important aspects that need to be taken into consideration.

In the present time, minimal processing of fresh fruits and vegetable produces has gained popularity among the consumers due to increased shelf life of the products, better presentability and ready to use, thus, minimizing the time of preparation. During minimal processing, fruits and vegetables are treated in a series of stages where their structure and tissues are generally

damaged or removed. By cutting, the size of diverse fruits and vegetables were reduced to obtain ready-to-use products that are packaged in small portions for convenience. During handling, cutting, washing and rinsing, important mechanical damage occurs, which is accompanied by oxidative stress.

Some notable consequences of these mechanisms are enzymatic browning and lignification of growing tissues, which damage various minimally processed products. Besides, the antioxidant capacity of this food group may be affected, with important consequences on nutritional quality.

In case of fruits, although they should be usually consumed in fresh form for maximum availability and effectiveness of phytochemicals, the advancement in the field of food processing has led to the development of number of techniques to increase the shelf life and availibility of the fruits throughout the year owing to their seasonal nature. Some of these processing techniques are pasteurization, spray drying, vacuum drying, freeze drying, cabinet drying, osmotic dehydration, storage at different temperature etc. But processing technique like drying involves application of heat which has detrimental effects on the fruit phytochemicals, vitamins and other nutrients as well as on organoleptic properties.

Therefore, objectives of the study were to investigate

- To determine the antioxidant capacity in fresh fruits and vegetables of Assam
- To measure the effect of processing treatments on the antioxidant properties
- To study the effect of temperature, and minimal processing on the antioxidant properties of fresh fruits and vegetables

MATERIALS AND METHODS

Part A: To measure the antioxidant capacity in fresh and processed viz. conventional boiled, steamed and microwave cooked in vegetables of Assam as well as the extraction efficiency of the four solvent taken viz. water, 80% ethanol, 80% methanol and 80% acetone.

Vegetable samples

a) Freshly harvested cauliflower (*Brassica oleracea* Botrytis), cabbage *(Brassica oleracea capitta)*, green pea (*Pisum sativa*), banana blossom (*Musa balbisiana*), brinjal (*Solanum melongena)*, beetroot (*Beta vulgaris)*, teaslegourd *(Momordica dioica*), black eyed pea (*Vigna unguiculata* subsp. *Unguiculata*), bottlegourd (*Lagenaria siceraria*), tomato (*Solanum lycopersicum)*, carrot *(Daucus carota subsp. Sativus)*, Kharua brinjal (*Solanum sp.)*, radish (*Raphanus sativus*), knol-khol (*Brassica caulorapa L.)* and roselle leaves (*Hibiscus acetosella*) were purchased from the local market of Tezpur, Assam. All the vegetables were sorted and washed properly before use. The cauliflower bunch was separated into florets and cut into uniform sizes. Other vegetables were also cut into uniform pieces. Each vegetable batch was divided into four equal portions. One portion was retained as raw, and the each of the remaining three were subjected to cooking methods of steaming, conventional boiling and microwave cooking, respectively.

b) Apart from the above treatments, four raw vegetables viz. ivy gourd (Coccinia grandis), ridge gourd (***Luffa acutangula***), french bean (*Phaseolus vulgaris)* and yardlong bean (***Vigna unguiculata* subsp. *sesquipedalis***) were analyzed for their phytochemical contents.

Cooking treatments

The vegetables were subjected to three cooking treatments- conventional boiling, steaming and microwave cooking. Prior to choosing the best cooking time for the vegetables, the individual vegetables were cooked by trial and error and the best cooking time was determined by taking into consideration the surface appearance and tender texture felt both by fingers and teeth. The cooking conditions for each treatment are given in Table 1.

Conventional boiling

Vegetables were added to boiling water in a covered stainless steel container (1:2 sample/water) and cooked.

Steaming

Vegetables were cooked in steam using an autoclave (Equitron) under atmospheric pressure.

Microwave cooking

The vegetables were cooked in a microwave (Samsung model) at 600W power level with water (1:1 sample/water).Immediately after the cooking treatments, the vegetables were cooled in an ice bath to stop the process of cooking and then stored at -20° C until analysis for phytochemicals and antioxidant activities.

Table 1. Cooking treatments and cooking time (min) for vegetables.

Sl. No	Sample name	Treatment	Time (min)
1	Cauliflower	Steaming	8
		Microwave (600W)	8
		Boiling	9
2	Cabbage	Steaming	7
		Microwave (600W)	7
		Boiling	5
3	Green pea	Steaming	5
		Microwave (600W)	5
		Boiling	6
4	Banana blossom	Steaming	5
		Microwave (600W)	7
		Boiling	8
5	Beetroot	Steaming	7
		Microwave (600W)	9
		Boiling	8
6	Teasle gourd	Steaming	8
		Microwave (600W)	4
		Boiling	10
7	Brinjal	Steaming	8
		Microwave (600W)	6
		Boiling	10
8	Black eyed pea	Steaming	6
		Microwave (600W)	5
		Boiling	7
9	Bottlegourd	Steaming	5
		Microwave (600W)	5
		Boiling	6
10	Tomato	Steaming	3

		Microwave (600W)	2
		Boiling	3
11	Carrot	Steaming	3
		Microwave (600W)	3
		Boiling	5
12	Kharua brinjal	Steaming	4
		Microwave (600W)	3
		Boiling	4
13	Radish	Steaming	5
		Microwave (600W)	4
		Boiling	5
14	Knol-khol	Steaming	5
		Microwave (600W)	4
		Boiling	5
15	Roselle leaves	Steaming	3
		Microwave (600W)	3
		Boiling	4

Part B: To study the effect of minimal processing on the antioxidant properties of fresh vegetables

For minimal processing, the selected vegetables viz., pointed gourd *(Trichosanthes dioica)*, teasel gourd *(Momordica dioica)* , yardlong bean (*Vigna unguiculata* subsp. *Sesquipedalis)* , squash (*Sechium edule)* and pumpkin *(cucurbita moschata)* were washed in running drinking water to remove dirt materials, then sanitized in 100 ppm sodium hypochlorite solution for 3 min and again rinsed off with drinking water. The excess water from the samples was absorbed off using a blotting paper. Subsequently, the vegetables were then divided into four lots and cut into uniform size with a sharp knife and then lot1 was immersed in water and kept as control raw, lot2 was blanched (75°C, 2 min), lot3 was dipped in 1% each of citric acid and ascorbic acid solution and lot4 was blanched and then dipped in 1% of citric acid and ascorbic acid solution. Each lot was packed (100g) in LDPE packaging pouches and sealed. The packs were stored at 8 °C under refrigerated condition. At interval of 3 days, samples were evaluated for changes in antioxidant properties.

Part C: To measure the antioxidant capacity in fresh and processed viz. pasteurized and dried with different methods in fruits of Assam.

1. Phytochemicals of fresh fruits

Freshly harvested raw *bael (Aegles mermelos)*, *bhimkal* (*Musa balbisiana*),*bogi jamun (Syzygium jambos)* , *amla (Emblica officinalis)*, Indian olive *(Elaeocarpus serratus),guava (Psidium guajava)*, *leteku* (*Baccurea sapida*), *carambola* (*Averrhoa carambola*), *black jamun (Syzygium cumuni)*, *poniol (Flacourtia catafracta Roxb*),watermelon (*Citrullus lanatus*), pineapple *(Ananas comosus)*, *hogplum (Spondias pinnata) and litchi* (*Litchi chinensis* Sonn.) were purchased from the local market of Tezpur, Assam. The fruits were washed properly. No cooking treatment was given to them. The fruits were analyzed for phytochemicals and antioxidant activity.

2. To analyse the phytochemicals in pasteurized fruit juices

The fruits selected for the study viz carambola (*Averrhoa carambola*), pineapple (*Ananas comosus*), watermelon (*Citrullus lanatus*), *pani jamun* or water apple (*Syzygium samarangense*), *black jamun (Syzygium cumini)* and *litchi* (*Litchi chinensis* Sonn.) were procured from the local market of Tezpur, Assam. The fruits were washed properly and then using a domestic juicer (Philips) the juice was separated from the pulp. The collected juice was then strained using a muslin cloth and then filled into pre-sterilized glass bottles. The juice bottles were then separated into two lots. One lot was kept as fresh, untreated juice and the other lot of juice was subjected to pasteurization at 75°C for 3 min and then cooled to room temperature. All the juices samples were then analysed for total phenolics, antioxidant activity and ascorbic acid content.

3. To analyse the phytochemical in fruits dried by different drying methods

The selected fruits viz. carambola (*Averrhoa carambola*), pineapple (*Ananas comosus)*, hog plum (*Spondias pinnata*), poniol (*Flacourtia catafracta Roxb*), leteku (*Baccurea sapida*), guava (*Psidium guajava*) and black jamun (*Syzygium cumini*) were purchased from the local market of Tezpur, Assam. The selected fruits were subjected to freeze drying (-50°C), vacuum drying (55 °C), and cabinet drying (55 °C) for 12 h. Apart from that, pineapple, watermelon, khasi mandarin (*Citrus reticulate)* and carambola juices were subjected to spray drying with 20% maltodextrin (DE 20) at an inlet temperature of 185 °C and outlet temperature of 88 °C with feed

rate of 7ml/min. All the fruit samples were then determined for changes in phytochemicals and antioxidant activities.

Part D: To study the changes in phytochemicals in selected two fruits viz. Litchi and black jamun stored at different temperature conditions for 6 days.

The freshly harvested two fruits were procured from the Tezpur local market, Assam. The fruits were washed and sorted properly and allowed to cool to room temperature. After that the fruits were divided in to three lots viz. Lot1 to be kept in deep freezer (-20°C), Lot2 to be kept at refrigerator temperature (8°C) and Lot 3 to be stored in an incubator at room temperature (25°C). The fruit samples were stored at these temperatures conditions for 6 (six) days and then analyzed for changes in phytochemicals and antioxidant activities on zero day and at an interval of two days subsequently.

Sample extraction

For the determination of phytochemicals and antioxidant activities both raw and cooked vegetables were extracted separately in water, 80% ethanol, 80% methanol and 80% acetone solvents. In case of the fruits and minimally processed vegetable, only 80% acetone solvent was used for extraction. The extraction was carried out following the method of Atala et al (2009). One gram of sample was homogenized and then extracted in 10 ml of solvent at 20° C for 90 min at 200 rpm and then centrifuged (Hettich centrifuge, Germany) at 970 g. The extracted supernatants were analyzed for total phenolic content, total flavonoid content, ferric reducing antioxidant potential, DPPH radical scavenging activity and metal chelation activity. The beet, roselle and stored fruits viz. black jamun samples were also studied for changes in total anthocyanin content.

Methods

Determination of total phenolic content

Total phenolic content in fruit extracts was assessed using a modified version of the Folin–Ciocalteu assay (Slinkard and Singelton, 1977). Gallic acid was used as a standard and the aqueous gallic acid solution (500 mg/L) was diluted with distilled water to give appropriate concentrations for a standard curve. For the analysis, 20µL each of fruit extract, gallic acid standard or blank were taken in separate test tubes and to each 1.58 mL of distilled water was

added, followed by 100µL of Folin–Ciocalteu reagent, mixed well and within 8 min, 300 µL of sodium carbonate was added. The samples were vortexed immediately and the tubes were incubated in the dark for 30 min at 40°C. The absorbance was then measured at 765 nm in a UV-Vis spectrophotometer (Cecil, Aquarius7400). The results were expressed in mg GAE/ 100g.

Determination of total flavonoid content

The flavonoid content was determined by aluminum trichloride method (Chang et al., 2002). Briefly, 0.5 mL of the extract was mixed with 1.5 mL of 95% ethanol, 0.1ml of 10% aluminum trichloride (AlCl3), 0.1 ml of 1M Potassium acetate, and 2.8 ml of deionised water. After incubation at room temperature for 40 min, the reaction mixture absorbance was measured at 415 nm against deionised water blank in a UV-Vis spectrophotometer (Cecil, Aquarius 7400). Results were expressed as quercetin equivalent (mgQE/100g) of sample.

Determination of ferric reducing antioxidant property (FRAP)

FRAP activity of the samples was measured by the method of Benzie and Strain (1999). Briefly, a 40 µL aliquot of properly diluted fruit extract was mixed with 3 mL of FRAP solution. The reaction mixture was incubated at 37°C for 4 min and the absorbance was determined at 593 nm in a UV-Vis spectrophotometer (Cecil, Aquarius 7400) against a blank that was prepared using distilled water. FRAP solution was pre warmed at 37°C and prepared freshly by mixing 2.5 ml of a 10mM 2,4,6-TPTZ [2,4,6-tri(2-pyridyl)-1,3,5-triazine] solution in 40mM hydrochloric acid with 2.5ml of 20mM ferric chloride and 25 mL of 0.3M acetate buffer (pH 3.6). A calibration curve was prepared, using an aqueous solution of ferrous sulfate (1-10 mM). FRAP values were expressed as µM of ferrous equivalent Fe (II) per 100 g of sample.

Determination of DPPH activity

Radical scavenging activity of the fruit extracts was measured by determining the inhibition rate of DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical (1995). Precisely, 100 µL of extracts were added to 1.4 mL DPPH radical methanolic solution (10^{-4} M). The absorbance at 517 nm was measured at 30 min against blank (100 µL methanol in 1.4 mL of DPPH radical solution) using a UV-Vis Spectrophotometer (Cecil Aquarius 7400). The results were expressed in terms of radical scavenging activity using the following equation:

Radical scavenging acitivity (%) = [(Ao-As)/ Ao] × 100

Where, Ao is absorbance of control blank, and As is absorbance of sample extract.

Determination of metal chelating capacity (MCC)

Metal chelating capacity was determined based on the given method (Carter, 1971; Dinis et al., 1994). 1.0 ml of 0.125 mM FeSO4 (Ferrous sulphate), and 1.0 ml of 0.3125 mM Ferrozine were mixed with 0.2 ml sample. The mixture was allowed to equilibrate for 10 min at room temperature before measuring the absorbance at 562 nm in a UV-Vis spectrophotometer (Cecil, Aquarius 7400) was recorded. The control contained all the reaction reagents except the extract. Decreased absorbance of the reaction mixture indicated increased activity.

Chelation activity [%] = [(Ao-As)/ Ao] ×100

Where, Ao is absorbance of control blank, and As is absorbance of sample extract

Total monomeric anthocyanin pigment content

Total monomeric anthocyanin pigment content of the fruit samples was determined with slight modifications of the pH differential methods of Giusti and Wrolstad (2001). Briefly, 0.5 mL of the sample extract was mixed thoroughly with 3.5 mL of 0.025M potassium chloride buffer (pH 1). The mix was vortexed and then allowed to stand for 15 min. The absorbance was then measured at 515 and 700 nm against distilled water in a UV–vis spectrophotometer (Cecil, Aquarius 7400). The extract was also mixed similarly with 0.025M sodium acetate buffer (pH 4.5), and the absorbance was measured at the same wavelength after standing for 15 min. Results were expressed as mg of cyanidin-3-glucoside equivalent/100 g of sample.

Total anthocyanin content = A x MW x DF x 1000/ ε x 0.01

Where, A (absorbance) = [(A515–A700) pH 1.0–(A515–A700) at pH 4.5]; MW is equal to 449.2 (molecular weight of cyanidin-3-glucoside); DF is the dilution factor of sample; ε is the molar absorbtivity of cyanidin-3-glucoside, equal to 26,900.

Ascorbic acid determination by Indophenol method

Ascorbic acid content was determined by using the 2, 6-dichlorophenol-indophenol dye method of Freed (1996). The 2.5 g of samples were ground with about 25 ml of 4% oxalic acid and filtered through Whatman No. 4 filter paper. The filtrate was collected in a 50 ml volumetric flask and the volume was made up with 4% oxalic acid and titrated against the indophenols dye to a pink point. The amount of ascorbic acid was calculated, using the formula given below, and expressed as mg/100 g on a fresh weight (FW) basis.

Ascorbic acid (mg/100g) = Titre value x dye factor x vol. made/ Aliqout of extract taken for estimation x Vol. of Sample taken for estimation

Statistical analysis

All experiments were carried out at least in triplicates and presented as mean ± standard deviation of mean (S.E.M) using SPSS version 11.5. The data were statistically analyzed by Duncan's multiple range tests at 5% significance level. For the pasteurized and spray dried data of fruit, Paired student t-test was conducted at 5 % significance level.

RESULTS AND DISCUSSION

Part A:

(i) To measure the antioxidant capacity in fresh and processed viz. conventional boiled, steamed and microwave cooked vegetables of Assam extracted in four different solvents viz. water, ethanol, methanol and acetone.

Total phenolic content (TPC)

TPC in the vegetables that were cooked by different cooking treatments got extracted in all the four solvents but in different amounts (Table 2). In most cases, there was statistically significant difference in the amount extracted by the four solvents. Cooking treatments were also found to affect the TPC in vegetables. Steam cooking retained maximum TPC in cauliflower florets. Methanol extraction of cauliflower florets gave highest value.

In green peas, processing had a negative effect on pea. The TPC in green pea was observed to be more soluble in water than the other solvents.

Raw banana blossom was found to be very rich in TPC with acetone extraction showing the highest extraction. Maximum TPC was observed in acetone and water extract of steamed samples. But for steamed ethanol and methanol extract a decrease in TPC values was observed. Overall, steaming retained TPC while microwaving and boiling had a negative impact.

In the case of brinjal, maximum extraction was obtained in ethanol and acetone. Heat had an overall increasing effect in the TPC values.

For beetroot, steam cooking showed values of 684.21 -1063.89 mgGAE/100g for all solvents compared to 1207.10-3378.79 mgGAE/100g for raw. All cooking treatments increased TPC in all the solvent extracts except in some cases. Steaming enhanced TPC the maximum followed closely by boiling.

In case of teasel gourd also, the TPC content increased on cooking by all treatments than the raw. The maximum TPC was observed in acetone extract of boiled samples 22.67-210.33 mgGAE/100g.

Cooking caused a detrimental effect on the total phenolic content in all the samples of black eyed pea except in boiled sample.

It was observed that cooking caused a significant change in the phenolic content in the selected vegetables. Usually, thermal treatments have destructive effect on the phenolic compounds as they are highly unstable compounds. But again, the decrease in phenolics depends on the severity of the heat treatments, exposure to the air, light, leaching of soluble phenolics into the cooking water etc. Usually, phenolics occur naturally in free and bound form. The free phenolics are easily extractable in solvents but the bound forms get extracted after cooking when heat breaks and softens the cellular matrix releasing the phenolics. Again, the phenolics can be hydrophilic or lipophilic depending on their solubility in water. The overall difference in the results of the total phenolics of the selected vegetables was due to the presence of different phenolic groups in the vegetables and their susceptibility to change or destruction during the three cooking treatments (Bernhardt & Schlich, 2006) and finally, their solubility and extractability in the four selected solvents according to the polarity of the compounds present.

Table 2. Changes in total phenolic content (mgGAE/100g, fresh weight) after cooking and extraction in different solvents

Treatment	Raw	Steamed	Microwaved	Boiled
Cauliflower florets				
Water	675.44 ± 0.11^{c}	675.68 ± 0.19^{c}	312.12 ± 0.14^{a}	531.07 ± 0.11^{b}
Ethanol	600.88 ± 0.39^{b}	815.32 ± 0.15^{c}	336.48 ± 0.18^{a}	717.51 ± 0.11^{c}
Methanol	815.79 ± 0.10^{c}	950.45 ± 0.25^{d}	355.34 ± 0.11^{a}	627.12 ± 0.16^{b}
Acetone	583.33 ± 0.12^{c}	684.68 ± 0.29^{d}	209.09 ± 0.17^{a}	446.33 ± 0.29^{b}
Green pea				
Water	455.07 ± 0.11^{c}	168.69 ± 0.10^{b}	165.71 ± 0.38^{b}	138.54 ± 0.12^{a}
Ethanol	159.42 ± 0.14^{c}	117.17 ± 0.12^{b}	102.86 ± 0.11^{a}	96.88 ± 0.18^{a}
Methanol	160.87 ± 0.15^{c}	143.43 ± 0.14^{b}	109.52 ± 0.27^{a}	107.29 ± 0.12^{a}
Acetone	184.06 ± 0.11^{c}	110.10 ± 0.07^{a}	144.76 ± 0.15^{b}	105.21 ± 0.16^{a}
Banana blossom				
Water	2029.63 ± 0.24^{c}	2780.00 ± 0.27^{d}	1400.00 ± 0.31^{c}	576.92 ± 0.19^{a}
Ethanol	3137.03 ± 0.22^{d}	1633.33 ± 0.16^{c}	1441.67 ± 0.13^{b}	846.15 ± 0.31^{a}
Methanol	3540.74 ± 0.14^{c}	1586.67 ± 0.12^{b}	1570.83 ± 0.19^{b}	935.89 ± 0.20^{a}
Acetone	5481.48 ± 0.29^{c}	6070.00 ± 0.21^{d}	5100.00 ± 0.28^{b}	2320.51 ± 0.21^{a}
Brinjal				
Water	278.22 ± 0.07^{a}	595.24 ± 0.15^{c}	498.62 ± 0.12^{b}	514.91 ± 0.12^{b}

Ethanol	459.32 ± 0.10^{b}	621.69± 0.18^{c}	526.17 ± 0.21^{b}	688.35 ± 0.15^{d}
Methanol	343.83 ± 0.12^{a}	574.07± 0.11^{d}	446.28 ± 0.16^{b}	585.36 ± 0.12^{c}
Acetone	438.32 ± 0.15^{a}	603.17 ± 0.15^{c}	484.85 ± 0.19^{a}	644.99 ± 0.06^{b}
Beetroot				
Water	883.33 ±0.14^{a}	3378.79±0.11 ^{c}	764.58± 0.12^{a}	1159.62 ± 0.20^{b}
Ethanol	684.21 ±0.22^{a}	1207.10± 0.17^{c}	1091.55 ± 0.18^{b}	1408.45 ± 0.14^{d}
Methanol	816.76 ± 0.15^{a}	1353.06± 0.14^{c}	1025.82 ± 0.11^{b}	1415.49 ± 0.18^{c}
Acetone	1063.89 ± 0.19^{a}	2003.03± 0.11 ^{c}	866.67 ± 0.15^{a}	1434.27 ± 0.22^{b}
Teasle gourd				
Water	913.89± 0.39^{a}	1353.85± 0.14^{b}	2024.24 ± 0.11^{c}	1222.22 ± 0.15 ^{b}
Ethanol	797.22 ± 0.15^{a}	1105.12 ±0.17^{c}	1006.67 ± 0.15^{b}	1669.69 ± 0.23^{d}
Methanol	886.11 ±0.13^{a}	1225.64 ±0.09^{b}	1066.67 ± 0.11^{b}	1818.18 ± 0.11^{c}
Acetone	1166.67± 0.18^{a}	1230.77±0.15^{a}	1146.67 ± 0.17^{a}	1912.12 ± 0.19^{b}
Black eyed pea				
Water	1069.05±0.28^{d}	514.81± 0.19^{a}	627.27± 0.20^{b}	781.82± 0.19^{c}
Ethanol	2066.67± 0.31^{c}	801.85± 0.11^{a}	1318.18± 0.24^{b}	1378.79± 0.29^{b}
Methanol	1504.76± 0.25^{d}	735.19±0.15^{a}	1003.03± 0.17^{b}	1293.93± 0.11^{b}
Acetone	2059.52± 0.22^{b}	1420.37± 0.27^{a}	1878.79± 0.18^{b}	2381.82± 0.15^{c}

* Means with the same letter within row are not significantly different at P≤0.05 by DMRT. Superscript of DMRT describes significant difference between the treatments

Total Flavonoid content (TFC)

The TFC in the selected vegetables showed varied results depending on the cooking treatment and extraction solvent. The results are shown in Table 3. Cooked cauliflower florets showed decrease in TFC when compared to raw florets. Maximum extraction occurred in water and ethanol. In green pea, maximum extraction was in acetone. Maximum loss in flavonoids was observed in microwaved samples. Except in water extracts of steamed and boiled samples, other treated sample extracts showed a decreasing effect on cooking. Similarly, TFC also decreased in drastically in boiled banana blossom. Water and acetone exhibited maximum extraction. In brinjal, cooking overall had a positive effect on the flavonoid content. Like brinjal, cooked beetroot showed increased TFC when compared to raw beetroot. Steaming and boiling had positive effects on the TFC. In teasel gourd, TFC increased in water extracts of all the cooked samples but the other solvents showed an overall decrease in TFC on cooking. The decrease could be due to polyphenol breakdown of the flavonoids as different flavonoids have got different susceptibility to temperature.

The TFC in black eyed pea showed a negative effect upon cooking. Maximum decrease was obtained in steamed samples.

Table 3. Changes in total flavonoid content (mgQE/100g, dry basis) after cooking and extraction in different solvents

Treatment	Raw	Steamed	Microwaved	Boiled
Cauliflower florets				
Water	122.81 ± 0.23^{e}	114.86 ± 0.27^{c}	59.09 ± 0.20^{a}	90.39 ± 0.29^{b}
Ethanol	267.54 ± 0.26^{d}	136.26 ± 0.23^{c}	66.82 ± 0.13^{a}	94.63 ± 0.23^{b}
Methanol	171.05 ± 0.18^{c}	45.04 ± 0.15^{a}	40.09 ± 0.06^{a}	73.45 ± 0.21^{b}
Acetone	482.46 ± 0.11^{d}	102.48 ± 0.09^{b}	87.12 ± 0.13^{a}	142.66 ± 0.18^{c}
Green pea				
Water	24.64 ± 0.03^{a}	66.67 ± 0.11^{c}	18.81 ± 0.13^{a}	53.13 ± 0.11^{b}
Ethanol	45.29 ± 0.14^{b}	39.89 ± 0.16^{b}	21.19 ± 0.23^{a}	44.27 ± 0.37^{b}
Methanol	12.32 ± 0.13^{b}	7.83 ± 0.15^{a}	7.14 ± 0.07^{a}	11.46 ± 0.13^{b}
Acetone	32.97 ± 0.11^{d}	26.77 ± 0.11^{c}	19.05 ± 0.11^{a}	23.18 ± 0.11^{b}
Banana blossom				
Water	239.81 ± 0.14^{d}	159.17 ± 0.11^{c}	133.33 ± 0.21^{b}	63.46 ± 0.17^{a}
Ethanol	$15.92 \pm 0.11^{c,b}$	$30.33 \pm 0.17^{e,d}$	$10.58 \pm 0.11^{c,a}$	$18.08 \pm 0.11^{b,c}$
Methanol	$10.67 \pm 0.09^{b,b}$	$17.17 \pm 0.18^{b,c}$	$6.42 \pm 0.11^{b,a}$	$21.92 \pm 0.10^{c,d}$
Acetone	359.26 ± 0.10^{d}	180.83 ± 0.13^{b}	273.96 ± 0.13^{c}	67.31 ± 0.15^{a}
Brinjal				
Water	99.74 ± 0.11^{a}	246.03 ± 0.10^{d}	158.40 ± 0.04^{b}	168.02 ± 0.11^{c}
Ethanol	129.26 ± 0.22^{a}	173.94 ± 0.11^{c}	141.87 ± 0.07^{b}	155.15 ± 0.19^{b}
Methanol	91.21 ± 0.16^{a}	126.32 ± 0.06^{c}	98.48 ± 0.03^{a}	113.14 ± 0.13^{c}
Acetone	125.32 ± 0.11^{a}	152.12 ± 0.17^{b}	120.52 ± 0.11^{a}	171.41 ± 0.10^{c}
Beetroot				
Water	304.86 ± 0.12^{b}	325.00 ± 0.10^{b}	206.82 ± 0.11^{a}	305.73 ± 0.19^{b}
Ethanol	146.89 ± 0.16^{a}	250.49 ± 0.11^{c}	169.01 ± 0.18^{b}	315.14 ± 0.13^{d}
Methanol	148.15 ± 0.11^{a}	252.46 ± 0.13^{b}	168.43 ± 0.13^{a}	325.12 ± 0.11^{c}
Acetone	200.69 ± 0.19^{a}	358.33 ± 0.17^{d}	137.91 ± 0.10^{a}	303.99 ± 0.16^{c}
Teasle gourd				
Water	57.64 ± 0.13^{a}	91.03 ± 0.14^{b}	108.33 ± 0.13^{c}	90.91 ± 0.10^{b}
Ethanol	115.97 ± 0.15^{c}	72.43 ± 0.17^{b}	55.00 ± 0.05^{a}	75.76 ± 0.13^{b}
Methanol	51.39 ± 0.11^{b}	33.33 ± 0.13^{a}	43.33 ± 0.11^{b}	39.39 ± 0.11^{a}
Acetone	87.03 ± 0.06^{c}	74.36 ± 0.11^{b}	41.67 ± 0.03^{a}	87.88 ± 0.15^{c}
Black eyed pea				
Water	208.93 ± 0.14^{c}	75.00 ± 0.09^{a}	138.64 ± 0.27^{b}	131.82 ± 0.11^{b}
Ethanol	782.14 ± 0.11^{c}	128.47 ± 0.17^{a}	237.50 ± 0.23^{b}	206.82 ± 0.17^{b}
Methanol	660.71 ± 0.18^{c}	65.28 ± 0.08^{a}	188.64 ± 0.21^{b}	106.82 ± 0.13^{b}
Acetone	495.83 ± 0.20^{c}	169.44 ± 0.19^{a}	293.18 ± 0.19^{b}	246.59 ± 0.10^{b}

* Means with the same letter within row are not significantly different at $P \leq 0.05$ by DMRT. Superscript of DMRT describes significant difference between the treatments

Ferric reducing antioxidant potential (FRAP)

The vegetables showed significant changes in the FRAP values upon cooking (Table 4). The cauliflower florets on steaming showed an increase in the FRAP values (6021.65-13951.45μM/100g) as compared to the raw sample (2725.99-3944.32μM/100g) except in some extracts of microwaved and boiled samples. In case of green pea, cooking caused an increase in the FRAP value on most of the cases with exception in the methanol extracts of steamed and microwaved peas. Steam cooking increased the FRAP values of acetone extract of banana blossom to a maximum of 64525.46μM/100g as compared to 55825.62μM/100g of raw blossom. But microwave and boiling treatments had an adverse effect on the FRAP values of banana blossom. Maximum extraction was in acetone solvent. The FRAP in brinjal showed an increasing trend after the cooking treatments. Maximum increase was observed in boiled samples (5137.76-5429.46μM/100g) followed by steaming and microwave cooking. Similarly, in beetroot also an increase in FRAP values was observed except in microwaved methanol extracts. The teasle gourd also showed an increase in FRAP values on cooking. The highest value was observed in aqueous extract (3665.12-14762.21μM/100g). But, exception was observed in case of acetone extract of microwave cooked samples where it showed a decrease to 925.93μM/100g from initial 2372.69μM/100g in raw. Likewise, FRAP values in cooked black eyed pea showed a decreasing trend with maximum destruction in steam cooked samples.

The possible reason for the above results could be that there are many hundreds of different antioxidants in food, and each has different characteristics of reacting to the changes in their cellular matrix caused by heat treatments or cooking. Cooking might have promoted a polymerization of polyphenols resulting in higher antioxidant activities (Nicoli et al., 1999). Steaming showed overall increase in antioxidants activity for all the selected vegetables with the exception of one or two vegetables. This effect is perhaps due to production of redox-active secondary plant metabolites or breakdown products, but is highly likely to be related to release of antioxidants from intercellular proteins, changes in plant cell wall structure and matrix modification (Rechkemmer et al., 2007).

Table 4 Changes in FRAP (uM/100g, dry basis) after cooking and extraction in different solvents

Treatment	Raw	Steamed	Microwaved	Boiled
Cauliflower				

florets				
Water	3944.32± 0.13^{a}	13951.45± 0.11^{c}	6302.61± 0.13^{b}	3668.39± 0.11^{a}
Ethanol	3941.32± 0.23^{a}	9843.17± 0.13^{b}	3581.41± 0.26^{a}	6277.46± 0.09^{e}
Methanol	2725.99± 0.19^{a}	7523.15± 0.18^{d}	4869.85± 0.18^{b}	6532.49± 0.13^{c}
Acetone	2756.46± 0.11^{b}	6021.65± 0.16^{d}	2420.03± 0.11^{a}	4041.12± 0.17^{c}
Green pea				
Water	417.67± 0.04^{a}	775.11± 0.11^{b}	744.05± 0.10^{b}	716.15± 0.07^{b}
Ethanol	603.86± 0.13^{b}	655.86± 0.14^{b}	472.88± 0.13^{a}	455.73± 0.13^{a}
Methanol	649.15± 0.11^{a}	701.46± 0.10^{a}	651.45± 0.06^{a}	792.10± 0.11^{b}
Acetone	1036.63± 0.10^{d}	512.06± 0.04^{a}	684.52± 0.03^{c}	589.55± 0.05^{b}
Banana blossom				
Water	16319.44± 0.33^{c}	30972.22± 0.13^{d}	10329.86± 0.37^{b}	5172.72± 0.39^{a}
Ethanol	14956.27± 0.13^{d}	13437.50± 0.27^{c}	12254.05± 0.17^{b}	7060.18± 0.23^{a}
Methanol	39570.47± 0.19^{d}	19745.37± 0.15^{c}	13729.75± 0.15^{b}	7683.40± 0.29^{a}
Acetone	55825.62± 0.29^{c}	64525.46± 0.18^{d}	44849.54± 0.13^{b}	20147.79± 0.34^{a}
Brinjal				
Water	1038.93± 0.13^{a}	1837.16± 0.11^{b}	1874.81± 0.13^{c}	5231.85± 0.11^{e}
Ethanol	1704.21± 0.11^{a}	3398.74± 0.10^{b}	1903.51± 0.17^{a}	5429.46± 0.13^{e}
Methanol	2004.96± 0.13^{a}	2985.38± 0.07^{b}	2200.03± 0.14^{a}	5137.76± 0.16^{e}
Acetone	2697.58± 0.16^{a}	3453.85± 0.13^{b}	2659.17± 0.19^{a}	5401.23± 0.23^{e}
Beetroot				
Water	4480.72± 0.13^{a}	8957.92± 0.27^{c}	6308.68± 0.23^{b}	8509.39± 0.34^{c}
Ethanol	7215.18± 0.15^{a}	12683.54± 0.24^{c}	8615.35± 0.27^{b}	12845.59± 0.27^{c}
Methanol	7892.03± 0.17^{a}	13621.79± 0.21^{b}	7898.08± 0.17^{a}	13244.98± 0.27^{b}
Acetone	7154.27± 0.27^{a}	16162.61± 0.28^{d}	8729.46± 0.29^{b}	12796.69± 0.21^{c}
Teasle gourd				
Water	3665.12± 0.27^{a}	13532.76± 0.15^{c}	8479.94± 0.11^{b}	14762.21± 0.15^{c}
Ethanol	2864.58± 0.15^{a}	5617.88± 0.17^{c}	3503.08± 0.25^{b}	8406.99± 0.11^{d}
Methanol	3067.13± 0.19^{a}	11965.81± 0.11^{c}	7854.94± 0.27^{b}	14215.07± 0.05^{d}
Acetone	2372.69± 0.25^{b}	3107.19± 0.19^{c}	925.93± 0.35^{a}	4071.97± 0.17^{d}
Black eyed pea				
Water	7155.26± 0.31^{d}	4735.73± 0.39^{a}	5713.38± 0.41^{b}	6328.91± 0.23^{c}
Ethanol	21192.96 ± 0.12^{c}	7040.89± 0.19^{a}	11363.64± 0.11^{b}	13257.58± 0.17^{d}
Methanol	16319.44± 0.29^{d}	6703.32± 0.24^{a}	8570.08± 0.18^{b}	10732.32±0.27^{c}
Acetone	22656.25± 0.33^{c}	6328.91± 0.28^{a}	18750.00± 0.23^{b}	27162.25± 0.19^{c}

* Means with the same letter within row are not significantly difference at P≤0.05 by DMRT. Superscript of DMRT describes significant different between the treatments

DPPH radical scavenging activity

The DPPH radical scavenging activity of the vegetables showed different changes with the cooking treatments as reported in Table 5. The raw cauliflower floret showed highest activity in

the methanol extract (30.71%). On cooking, microwaving and boiling treatment caused a decrease in DPPH activity. Steaming had a positive effect on radical scavenging activity. In green pea also, an increase was observed on steaming but other treatments doesn't show any significant difference on cooking. In case of banana blossom, raw sample showed good DPPH activity (78.71-92.15%). On steaming, good amount of the activity was retained but microwave and boiling treatments seemed to have a negative impact on the radical scavenging activity. But, acetone extract of all the samples did not show major change in their activity. Again, this could be attributed to the different solubility pattern of the phenolic compounds responsible for the DPPH activity in the selected solvents.

In brinjal all the treated samples showed a good increase in the DPPH activity than the raw (2.54-10.66%). Highest activity was found in steamed brinjal (29.64-45.61%) followed by microwaved and boiled samples.

The DPPH activity in beetroot also showed an increasing trend on cooking. Highest activity was recorded in steam cooking (51.38%) followed by boiling and microwave cooking. In teasel gourd, the DPPH activity showed manifold increase than the raw one. Highest value was observed in boiled samples (48.65-59.89%) followed by microwave and steam cooking. However, in black eyed pea cooking decreased the DPPH activity in most cases compared to the raw samples.

The above increase in DPPH activity in the cooked samples could be due to the increased extractability of the phenolic compounds. Manzocco et al. (2001) and Nicoli et al. (1999) have reported that, in some cases, processing causes enhancement of antioxidant properties of naturally occurring compounds or formation of novel compounds such as Maillard reaction products having antioxidant activity. Moreover, the lipophilic phenolic compounds could play a major role in the DPPH antioxidant activity as they usually do not get leached out into the cooking medium.

Table 5. Changes in DPPH (%, fresh weight) after cooking and extraction in different solvents

Treatment	Raw	Steamed	Microwaved	Boiled
Cauliflower florets				
Water	24.45± 0.35^{b}	41.42± 0.15^{c}	10.86± 0.14^{a}	12.08± 0.15^{a}

Ethanol	8.80± 0.39^{b}	30.72± 0.25^{d}	4.06± 0.25^{a}	24.39± 0.13^{c}
Methanol	30.71± 0.15^{c}	34.53± 0.11^{c}	11.45± 0.15^{a}	26.20± 0.10^{b}
Acetone	7.30± 0.17^{a}	19.53± 0.18^{c}	11.77± 0.19^{b}	11.00± 0.12^{b}
Green pea				
Water	5.28± 0.15^{a}	13.05± 0.10^{b}	6.32± 0.15^{a}	6.82± 0.18^{a}
Ethanol	5.19± 0.11^{a}	13.46± 0.15^{b}	6.07± 0.13^{a}	7.08± 0.20^{a}
Methanol	6.03± 0.05^{a}	18.08± 0.11^{b}	8.88± 0.11^{a}	8.65± 0.15^{a}
Acetone	7.35± 0.07^{a}	10.30± 0.16^{b}	10.23± 0.11^{b}	8.51± 0.17^{a}
Banana blossom				
Water	83.33± 0.35^{c}	92.05± 0.28^{d}	52.54± 0.28^{b}	48.39± 0.38^{a}
Ethanol	78.71± 0.25^{c}	81.65± 0.23^{d}	62.52± 0.26^{b}	62.02± 0.28^{a}
Methanol	92.15± 0.19^{d}	90.44± 0.15^{c}	68.24± 0.23^{a}	71.17± 0.23^{b}
Acetone	91.19± 0.31^{b}	92.89± 0.21^{c}	90.27± 0.18^{a}	91.45± 0.26^{b}
Brinjal				
Water	2.54± 0.08^{a}	29.64± 0.18^{c}	27.74± 0.18^{c}	19.87± 0.28^{b}
Ethanol	13.98± 0.28^{a}	41.43± 0.28^{c}	29.57± 0.29^{b}	27.99± 0.29^{b}
Methanol	7.68± 0.22^{a}	43.08± 0.18^{c}	31.00± 0.27^{b}	27.88± 0.32^{b}
Acetone	10.66± 0.21^{a}	45.61± 0.23^{c}	37.20± 0.21^{b}	34.63± 0.38^{b}
Beetroot				
Water	3.36± 0.18^{a}	43.81± 0.28^{d}	19.32± 0.21^{b}	27.45± 0.28^{c}
Ethanol	20.79± 0.28^{a}	42.70± 0.25^{d}	31.26± 0.28^{b}	37.31± 0.25^{c}
Methanol	23.97± 0.20^{a}	49.66± 0.28^{d}	36.54± 0.19^{c}	30.66± 0.22^{b}
Acetone	24.96± 0.23^{a}	51.38± 0.30^{d}	35.21± 0.26^{b}	41.48± 0.27^{c}
Teasle gourd				
Water	1.89± 0.08^{a}	32.22± 0.08^{b}	42.09± 0.05^{c}	52.89± 0.03^{d}
Ethanol	2.98± 0.28^{a}	14.54± 0.18^{b}	37.03± 0.28^{c}	54.32± 0.18^{d}
Methanol	5.02± 0.32^{a}	34.44± 0.22^{b}	41.87± 0.33^{b}	59.89± 0.28^{c}
Acetone	0.33± 0.03^{a}	19.10± 0.28^{b}	35.52± 0.37^{c}	48.65± 0.30^{d}
Black eyed pea				
Water	57.82± 0.16^{c}	37.85±0.10^{b}	30.88±0.17^{b}	25.65± 0.22^{a}
Ethanol	91.90± 0.19^{b}	70.92± 0.12^{a}	72.10± 0.12^{a}	76.49± 027^{a}
Methanol	88.86± 0.21^{c}	67.94± 0.27^{b}	54.78± 0.31^{a}	61.30± 0.31^{b}
Acetone	91.06± 0.11^{b}	75.82± 0.23^{a}	80.43± 0.27^{a}	91.34± 0.25^{b}

* Means with the same letter within row are not significantly different at P≤0.05 by DMRT. Superscript of DMRT describes significant different between the treatments

Metal chelation capacity (MCC)

The MCC of the cauliflower florets didn't show much variation between the cooked and raw samples in most cases (Table 6). But in green pea, a maximum increase in MCC was observed in water and acetone extracts of steamed and microwaved samples compared to raw sample.

Boiling did not show major change in MCC except in the aqueous extract where it recorded 11.64% compared to 2.21% in the aqueous extract of the raw. Likewise in banana blossom and brinjal, the MCC showed no major change on cooking except in one or two instances.

Interestingly, the beetroot didn't show any activity for MCC both in the raw and cooked samples. In teasle gourd, MCC decreased on cooking when compared to the raw sample (10.12-17.46%). The decrease was more in boiled samples followed by microwave and steam cooked samples.

In case of black eyed pea, except raw aqueous extract cooking enhanced the MCC values in all the samples.

Again, the pattern of increase or decrease in the MCC could be due to the different solubility behavior of the antioxidants in the selected solvents and effect of heat treatments on the characteristics of the compounds responsible for the MCC.

Table 6. Changes in MCC (%, fresh weight) after cooking and extraction in different solvents

Treatment	Raw	Steamed	Microwaved	Boiled
Cauliflower florets				
Water	3.15± 0.08^{a}	3.95± 0.11^{a}	5.36± 0.18^{b}	4.75± 0.13^{b}
Ethanol	7.94± 0.11^{b}	4.48± 0.12^{a}	4.32± 0.10^{a}	6.88± 0.19^{b}
Methanol	8.53± 0.10^{c}	3.68± 0.09^{a}	5.41± 0.11^{b}	5.92± 0.11^{b}
Acetone	5.79± 0.15^{a}	5.89± 0.16^{a}	5.17± 0.12^{a}	4.97± 0.14^{a}
Green pea				
Water	2.21± 0.15^{a}	14.67± 0.11^{c}	9.89± 0.14^{b}	11.64± 0.16^{b}
Ethanol	7.97± 0.19^{a}	8.99± 0.13^{a}	7.97± 0.11^{a}	9.08± 0.10^{a}
Methanol	8.01± 0.11^{a}	9.92± 0.10^{a}	8.53± 0.08^{a}	8.19± 0.11^{a}
Acetone	6.26± 0.12^{a}	8.36± 0.15^{c}	7.28± 0.13^{b}	6.60± 0.17^{a}
Banana blossom				
Water	5.98± 0.11^{a}	8.84± 0.10^{b}	10.75± 0.11^{c}	8.02± 0.06^{b}
Ethanol	10.32± 0.06^{a}	10.66± 0.11^{a}	10.03± 0.15^{a}	10.65± 0.11^{a}
Methanol	9.89± 0.17^{b}	9.31± 0.18^{b}	12.73± 0.19^{c}	7.48± 0.13^{a}
Acetone	6.08± 0.12^{a}	7.35± 0.13^{b}	8.20± 0.08^{c}	9.23± 0.10^{d}
Brinjal				
Water	6.66± 0.04^{c}	4.39± 0.11^{a}	5.64± 0.19^{b}	6.21± 0.11^{c}
Ethanol	6.69± 0.03^{c}	7.03± 0.07^{c}	5.86± 0.13^{b}	4.68± 0.12^{a}

Methanol	7.98± 0.11^{b}	6.65± 0.11^{a}	9.18± 0.11^{c}	7.14± 0.17^{b}
Acetone	7.66± 0.13^{b}	5.54± 0.16^{a}	8.72± 0.10^{c}	11.87± 0.15^{d}
Teasle gourd	10.12± 0.11^{c}	7.94± 0.05^{b}	3.99± 0.10^{a}	4.56± 0.11^{a}
Water	17.46± 0.10^{c}	8.79± 0.03^{b}	8.88± 0.11^{b}	3.99± 0.16^{a}
Ethanol	13.69± 0.06^{c}	8.76± 0.11^{b}	4.37± 0.13^{a}	3.37± 0.14^{a}
Methanol	14.42± 0.07^{c}	7.34± 0.13^{b}	7.43± 0.15^{b}	3.51± 0.10^{a}
Acetone				
Black eyed pea	4.01±0.09^{c}	2.27± 0.11^{a}	3.40± 0.17^{b}	3.18± 0.09^{b}
Water	1.89±0.05^{a}	3.63± 0.13^{b}	3.28± 0.11^{b}	3.02±0.07^{b}
Ethanol	1.98±0.02^{a}	4.39± 0.11^{c}	4.84± 0.11^{c}	3.33± 0.11^{b}
Methanol	2.72±0.10^{a}	2.11± 0.09^{a}	4.61± 0.10^{b}	3.18± 0.14^{a}
Acetone				

* Means with the same letter within row are not significantly different at P≤0.05 by DMRT. Superscript of DMRT describes significant different between the treatments

(ii) Changes in TPC, TFC, FRAP, DPPH and MCC of acetone extract of the selected vegetables after giving cooking treatments

After referring to the above discussed results, it can be inferred that acetone can be the most suitable solvent for the extraction of phytochemicals. Therefore, the vegetables mentioned below (Table 7) had been extracted only in acetone and analyzed for their phytochemical content and antioxidant activity in after cooking treatments.

The change in the phenolic and antioxidant activity in cooked cabbage was studied using only 80% acetone as an extracting solvent. The results were reported in Table 7. It was observed that steaming increased the TPC but boiling had a drastic effect on it. Ismail et al. (2004) showed that heating decreased the TPC in cabbage, kale and spinach. However, TFC showed an increase to 85.45mg/100g and 69.88mg/100g in steamed and microwaved samples, respectively when compared to 35.14mg/100g in the raw cabbage. FRAP values decreased in microwaved cooked and boiled samples. Highest decrease was observed in microwave cooked samples. But steaming had a positive effect. Similarly, DPPH activity also decreased drastically from 30.62% in raw to 2.37% in boiled, 3.59 % in microwaved and 6.16% in steamed cabbage samples. The cooking treatments did not have much impact on the MCC values of microwaved sample but showed a decrease in steamed and boiled samples.

The TPC in bottlegourd showed no significant change apart from steamed sample on cooking. But showed a decreased value for TFC and FRAP. However, increased DPPH activity as well as MCC value was obtained after cooking treatment with exception in microwaved samples.

Similarly, in radish decrease in TPC was obtained however steaming retained much of the phenolics compared to microwaving and boiling treatments. Steaming increased the total flavonoid values. FRAP values increased on cooking in all the samples with maximum value exhibited by steamed radish. But cooking had a detrimental effect on the DPPH activity. However, except boiled samples, cooking enhanced the MCC values. In tomato, except boiled samples, other two cooking treatments enhanced the phenolic content. Also an increased TFC was observed. Similarly, an increase in MCC values of steamed and microwaved samples was observed. But DPPH showed a decreasing trend on application of heat.

Kharua brinjal showed good phenolic content. Cooking enhanced the TPC as well as TFC except in boiled sample. Similarly, an increase in FRAP values was observed on cooking. Except in some cases, DPPG and MCC values also showed an increasing effect on cooking. In case of knol-khol, cooking caused an increase in TPC, TFC and FRAP. Maximum increase was in microwaved sample. Minimum DPPH and MCC values were shown by boiled sample.

Except in boiled carrot, cooking increased the TPC in steamed and microwaved samples. Enhanced TFC was observed on cooking with maximum effect in steamed sample. In case of FRAP, steamed samples showed no significant change compared to the raw untreated carrot. But an increased DPPH activity and metal chelation capacity was observed post treatment but with some exceptions.

Lastly, in roselle leaves (red variety) cooking had a detrimental effect on the phytochemical and antioxidant activities. When compared to the microwaved cooking and boiling treatments, steaming retained good phytochemical properties except the metal chelation capacity.

So overall, cooking had caused a decrease in the total phenolics, flavonoid and antioxidant activity in the raw cabbage. The reason behind the decrease could be the different characteristics of the compounds responsible for antioxidant activity and their solubility in the extracting solvent.

Apart from solvent used for extraction, the antioxidant activity is likely to depend on several factors, such as the cooking procedure, degree of heating, leaching into cooking medium, pH, and surface area exposed to water and oxygen. Moreover, different plants contain various compounds some of which are thermally labile and some are not and therefore, the same cooking method may have different effects on different types of plants (Bernhardt & Schlich, 2006).

The result presented here clearly shows that cooking can make the polyphenol and antioxidant of cooked food quite different from that of uncooked food. This is probably due to variety of effects like destruction, release and transformation of the phytochemicals. In the present study, steaming showed an enhancement in the phytochemicals and antioxidant activity followed by microwaving and then boiling. The extraction yield of the solvent also varied for different solvent but extraction was more in acetone and methanol followed by ethanol and water.

From the above results, steaming is the preferred cooking method for the studied vegetables to enhance the potential to obtain phytochemicals with antioxidant activity.

Table 7.Changes in TPC, TFC, FRAP, DPPH and MCC of acetone extract of the selected vegetables after giving cooking treatments

Treatment	Raw	Steamed	Microwaved	Boiled
Cabbage				
TPC (mgGAE/100g)	266.64 ± 0.23^{b}	567.14 ± 0.29^{c}	272.07 ± 0.11^{b}	250.00 ± 0.09^{a}
TFC(μg/100g)	35.14 ± 0.19^{a}	85.45 ± 0.25^{c}	69.88 ± 0.19^{b}	46.41 ± 0.17^{a}
FRAP(μM/100g)	1512.93 ± 0.28^{c}	2235.45 ± 0.12^{d}	425.75 ± 0.14^{a}	1103.12 ± 0.28^{b}
DPPH (%)	30.62 ± 0.18^{c}	6.16 ± 0.14^{b}	3.59 ± 0.12^{a}	2.37 ± 0.13^{a}
MCC (%)	7.39 ± 0.19^{b}	6.28 ± 0.10^{a}	7.55 ± 0.17^{b}	5.98 ± 0.15^{a}
Bottlegourd				
TPC (mgGAE/100g)	406.25 ± 0.29^{b}	319.15 ± 0.27^{a}	393.94 ± 0.19^{b}	386.36 ± 0.29^{b}
TFC(μg/100g)	125.00 ± 0.12^{c}	58.51 ± 0.22^{a}	45.45 ± 0.32^{a}	73.86 ± 0.13^{b}
FRAP(μM/100g)	3356.72 ± 0.17^{c}	1548.19 ± 0.19^{a}	3018.75 ± 0.29^{b}	2913.75 ± 0.19^{b}
DPPH (%)	3.77 ± 0.09^{a}	25.58 ± 0.15^{d}	18.17 ± 0.13^{b}	22.03 ± 0.16^{c}
MCC (%)	3.89 ± 0.07^{b}	5.73 ± 0.11^{c}	2.28 ± 0.10^{a}	7.06 ± 0.10^{c}
Radish				
TPC (mgGAE/100g)	837.50 ± 0.16^{d}	647.73 ± 0.23^{c}	493.51 ± 0.22^{b}	337.35 ± 0.17^{a}
TFC(μg/100g)	45.31 ± 0.17^{b}	60.61 ± 0.11^{c}	19.48 ± 0.14^{a}	22.59 ± 0.05^{a}
FRAP(μM/100g)	1862.44 ± 0.11^{a}	3176.25 ± 0.39^{c}	2182.50 ± 0.29^{b}	2066.48 ± 0.11^{b}
DPPH (%)	21.72 ± 0.07^{c}	2.86 ± 0.05^{b}	0.52 ± 0.03^{a}	3.96 ± 0.06^{b}
MCC (%)	3.18 ± 0.05^{a}	8.28 ± 0.10^{b}	6.55 ± 0.09^{b}	3.69 ± 0.10^{a}

Tomato				
TPC (mgGAE/100g)	443.66±0.11^{a}	633.33±0.19^{c}	577.59±0.07^{b}	485.50±0.17^{a}
TFC(µg/100g)	112.68±0.13^{a}	216.67±0.24^{c}	213.36±0.19^{c}	182.97±0.21^{b}
FRAP(µM/100g)	2151.80±0.17^{a}	4652.78±0.23^{c}	3621.89±0.11^{b}	5308.98±0.27^{c}
DPPH (%)	16.18±0.10^{a}	44.31±0.15^{b}	44.78±0.13^{b}	43.49±0.19^{b}
MCC (%)	4.66±0.08^{b}	2.63±0.04^{a}	4.86±0.10^{b}	3.26±0.16^{a}
***Kharua* Brinjal**				
TPC (mgGAE/100g)	1516.13±0.12^{a}	2449.44±0.11^{c}	2617.65±0.34^{d}	1623.29±0.11^{b}
TFC(µg/100g)	446.24±0.08^{b}	529.49±0.34^{c}	527.57±0.11^{c}	375.00±0.09^{a}
FRAP(µM/100g)	8923.32±0.26^{a}	19505.24±0.37^{c}	22165.83±0.32^{d}	14049.88±0.41^{b}
DPPH (%)	47.79±0.18^{a}	85.50±0.21^{c}	61.22±0.21^{b}	44.58±0.39^{a}
MCC (%)	4.46±0.07^{b}	3.14±0.04^{a}	5.14±0.10^{b}	3.37±0.09^{a}
Knol-khol				
TPC (mgGAE/100g)	199.47±0.22^{a}	386.36±0.23^{c}	564.36±0.13^{d}	340.52±0.23^{b}
TFC(µg/100g)	15.29±0.25^{a}	40.72±0.11^{c}	45.79±0.22^{d}	35.56±0.21^{b}
FRAP(µM/100g)	331.76±0.11^{a}	1561.88±0.33^{c}	2984.71±0.42^{d}	1209.76±0.26^{b}
DPPH (%)	4.79±0.10^{c}	1.72±0.03^{b}	6.93±0.20^{d}	0.86±0.05^{a}
MCC (%)	4.08±0.09^{b}	5.75±0.04^{c}	1.92±0.07^{a}	2.76±0.11^{a}
Carrot				
TPC (mgGAE/100g)	206.52±0.31^{a}	326.61±0.23^{b}	508.47±0.11^{c}	253.33±0.27^{a}
TFC(µg/100g)	40.76±0.23^{a}	81.65±0.22^{c}	133.47±0.13^{d}	59.17±0.29^{b}
FRAP(µM/100g)	1148.72±0.21^{a}	1131.71±0.35^{a}	2995.17±0.17^{c}	1755.60±0.37^{b}
DPPH (%)	3.87±0.15^{a}	11.06±0.13^{d}	7.30±0.09^{c}	6.23±0.22^{b}
MCC (%)	4.29±0.09^{b}	4.60±0.10^{b}	5.37±0.06^{c}	2.22±0.10^{a}
Roselle				
TPC (mgGAE/100g)	3118.11±0.17^{d}	2178.57±0.25^{c}	1723.14±0.33^{b}	1487.80±0.29^{a}
TFC(µg/100g)	269.75±0.20^{c}	190.63±0.34^{b}	116.75±0.12^{a}	109.50±0.23^{a}
FRAP(µM/100g)	4482.64±0.27^{d}	3281.25±0.23^{c}	2434.03±0.39^{b}	1906.25±0.21^{a}
DPPH (%)	64.15±0.21^{d}	48.79±0.22^{c}	34.26±0.09^{a}	41.31±0.09^{b}
MCC (%)	6.11±0.20^{b}	4.88±.06^{a}	7.43±0.02^{b}	5.03±0.10^{a}
Total anthocyanin content (mg/100g)	38.22±0.19^{c}	32.46±0.11^{b}	19.28±0.11^{a}	30.30±0.13^{b}

* * Means with the same letter within row are not significantly different at P≤0.05 by DMRT. Superscript of DMRT describes significant difference between the treatments

(iii) Phytochemicals and antioxidant activity of the selected fresh vegetables

Three vegetables viz., ridge gourd (*Luffa acutangula*), ivy gourd(*Coccinia grandis*) and french bean *(Phaseolus vulgaris*) was found to contain very low amount of phenolics and antioxidant activity compared to other vegetable samples. Therefore, only the results of the uncooked sample

extracts had been shown (Table 8.) and discussed. All the raw uncooked vegetable samples showed phenolic content between the ranges of 20.00-89.00mgGAE/100g depending on the type of solvent used for extraction. Highest TPC was observed by acetone extract of french bean (89.00 mgGAE/100g) followed by Ivy gourd (37mg/100g). In case of ridge gourd, ethanol, methanol, and acetone extract's TPC was more than the water extract. Similarly, maximum TFC was present in French bean (8.17-41.42 mgQE/100g). French bean exhibited highest FRAP values (83.33-685.76 µM/100g) compared to Ivy gourd (85.07-144.00 µM/100g). The ridge gourd didn't showed ferric reducing antioxidant potential activity. Likewise, water and ethanol extract of ridge gourd showed no DPPH radical scavenging activity but methanol and acetone exhibited 3.09 % and 3.50% DPPH activity, respectively. Similarly, water extract of ivy gourd and french bean showed no DPPH activity at all. But the acetone extract of french bean exhibited 32.84% of activity. The metal chelation potential of ridge gourd is relatively high (16.87-17.60%) compared to ivy gourd (3.10-4.57%) and french bean (1.17-3.35%).The main reason for different phenolic content and antioxidant activity values for the selected four solvent extracts is due to different solubility and polarity of the phytochemicals.

Table 8. Phytochemicals and antioxidant activity of the selected fresh vegetables extracted in different solvents

Samples	Water	Ethanol	Methanol	Acetone
Ridge gourd				
TPC (mgGAE/100g)	14.00± 0.09^a	20.00±0 .11^b	23.00± 0.11^b	20±0.12^b
TFC (mgQE/100g)	3.25± 0.03^b	2.75± .07^a	3.25± 0.09^b	3.5± 0.04^b
FRAP (µM/100g)	n.d	n.d	n.d	n.d
DPPH (%)	n.d	n.d	3.09±.03^a	3.50±0.09^a
MCC (%)	17.60± 0.12^a	18.58± 0.18^b	18.21± 0.17^b	16.87± 0.20^a
Ivy gourd				
TPC (mgGAE/100g)	29.00± 0.22^a	31.00± 0.23^a	32.00± 0.22^a	37.00± 0.20^b
TFC (mgQE/100g)	7.42± 0.11^b	10.33± 0.11^c	4.42± 0.10^a	9.25± 0.16^c
FRAP (µM/100g)	144.09± 0.23^c	85.07± 0.29^a	114.58± 0.31^b	111.11± 0.33^b
DPPH (%)	n.d	0.73± 0.01^a	8.44 ± 0.05^b	0.51± 0.02^a
MCC (%)	4.32± 0.09^b	3.30± 0.05^a	4.57± 0.05^b	3.10± 0.03^a
French bean				
TPC (mgGAE/100g)	31.00± 0.09^a	52.00± 0.18^b	66.00± 0.21^c	89.00± 0.19^d
TFC (mgQE/100g)	8.17± 0.31^a	33.75± 0.33^c	25.58± 0.28^b	41.42± 0.23^d
FRAP (µM/100g)	83.33± 0.29^a	331.59± 0.41^b	451.39± 0.48^c	685.76± 0.39^d
DPPH (%)	n.d	19.97± 0.27^a	28.46± 0.11^b	32.84± 0.21^c
MCC (%)	1.22± 0.07^a	3.35± 0.08^b	1.17± 0.03^a	1.98± 0.01^a

* * Means with the same letter within row are not significantly different at P≤0.05 by DMRT. Superscript of DMRT describes significant difference between the solvents

Part B: To study the effect of minimal processing on the antioxidant properties of fresh vegetables

The results are shown in Table 9a. Among the three lots, lot2 (blanched) and lot3 (1% citric acid +ascorbic acid dipped) showed highest phenolic content and antioxidant activity on '0' day in all the vegetables compared to the control raw. In case of pointed and teasel gourd, phenolic content increased with storage except in one or two cases. But, yardlong bean exhibited a decrease in phenolic content in control raw (lot1). The remaining two lots showed an increasing trend except in some cases. But on 9th day, in all the samples, drop in phenolic value was observed. Similarly, flavonoid content showed an increasing trend in all the three vegetables during storage but decreased on 9th day. The FRAP values for the three vegetables decreased substantially during the storage period. In case of DPPH and MCC values, the vegetables showed a decreasing trend and on the 9th day no activity was detected except in yardlong bean where, DPPH radical scavenging activity was observed.

Table 9 (a) Changes in phytochemicals and antioxidant activity in minimally processed Yardlong bean, teasle gourd and pointed gourd

Samples	TPC (mgGAE/100g)	TFC (mgQE/100g)	FRAP (uM/100g)	DPPH (%)	MCC (%)
Yardlong bean					
D-0					
R	111.00 ± 0.29^{a}	42.00± 0.25^{a}	450.45± 0.31^{a}	24.23± 0.23^{a}	18.78± 0.21^{b}
B	116.50± 0.42^{a}	47.5± 0.31^{b}	1058.56± 0.27^{c}	56.49± 0.20^{c}	17.60± 0.17^{b}
CA	122.50± 0.22^{a}	57.5± 0.25^{b}	434.86± 0.29^{a}	24.07± 0.31^{a}	14.85± 0.34^{a}
D-3					
R	109.00± 0.18^{a}	43.12± 0.29^{b}	47.64± 0.11^{c}	32.48± 0.15^{b}	4.27± 0.10^{b}
B	98.50± 0.19^{a}	49.25± 0.24^{c}	39.33± 0.17^{b}	27.04± 0.14^{b}	4.78± 0.13^{b}
CA	183.00± 0.28^{d}	44.13± 0.18^{b}	69.30± 0.11^{d}	39.61± 0.30^{c}	2.87± 0.05^{a}
D-6					
R	108.5± 0.34^{a}	50.25± 0.40^{b}	60.46± 0.23^{a}	31.75± 0.26^{b}	n.d.
B	134.00± 0.43^{b}	68.88± 0.47^{c}	67.57± 0.19^{b}	31.26± 0.11^{b}	0.75± 0.03^{a}
CA	143.00± 0.19^{b}	42.50± 0.22^{a}	87.84± 0.19^{c}	37.38± 0.11^{c}	n.d.
D-9					
R	73.00± 0.19^{b}	19.13± 0.11^{b}	36.55± 0.9^{b}	22.36± 0.18^{b}	n.d
B	109.50± 0.34^{c}	26.00± 0.19^{c}	45.56± 0.21^{c}	32.88± 0.26^{c}	n.d
CA	136.5± 0.29^{d}	18.50± 0.22^{b}	73.80± 0.29^{d}	43.17± 0.30^{d}	n.d.

Teasle gourd					
D-0					
R	90.00± 0.22^{a}	9.53± 0.21^{b}	329.18± 0.19^{b}	8.81± 0.20^{c}	17.48± 0.13^{b}
B	89.50± 0.28^{a}	4.38± 0.11^{a}	194.04± 0.48^{a}	4.07± 0.05^{b}	13.20± 0.11^{a}
CA	141.50± 0.27^{c}	12.75± 0.10^{c}	488.57± 0.49^{c}	17.06± 0.12^{d}	16.99± 0.09^{b}
D-3					
R	99.50± 0.27^{a}	5.75± 0.04^{b}	20.44± 0.33^{b}	2.39± 0.05^{a}	16.67± 0.21^{d}
B	134.50± 0.25^{b}	4.25± 0.02^{a}	25.64± 0.31^{b}	9.56± 0.11^{c}	2.87± 0.16^{a}
CA	110.50± 0.43^{a}	6.25± 0.04^{b}	14.73±0.11^{a}	4.56± 0.07^{b}	11.48± 0.11^{c}
D-6					
R	106.00± 0.31^{a}	13.50± 0.17^{c}	17.33± 0.19^{b}	9.23± 0.17^{d}	1.61± 0.07^{a}
B	103.00± 0.33^{a}	5.75± 0.05^{a}	6.93± 0.11^{a}	1.78± 0.02^{a}	0.75± 0.04^{a}
CA	163.50± 0.29^{b}	10.00± 0.08^{b}	53.53± 0.16^{c}	6.10± 0.11^{c}	0.68± 0.02^{a}
D-9					
R	111.00± 0.11^{b}	8.88± 0.08^{b}	12.30± 0.21^{a}	n.d	n.d
B	79.00± 0.18^{a}	6.13± 0.13^{a}	11.26± 0.27^{a}	n.d	n.d
CA	117.50± 0.25^{b}	8.75± 0.10^{b}	23.39± 0.23^{b}	n.d	n.d
Pointed gourd					
D-0					
R	32.50± 0.23^{a}	5.25± 0.11^{a}	27.72± 0.15^{a}	4.38± 0.11^{a}	18.82±0.29^{a}
B	49.00± 0.13^{b}	11.63± 0.13^{b}	65.84± 0.11^{c}	5.21± 0.13^{b}	18.58± 0.18^{a}
CA	71.50± 0.29^{c}	24.88± 0.16^{d}	43.31± 0.36^{b}	5.21± 0.11^{b}	19.56± 0.11^{a}
D-3					
R	68.50± 0.23^{c}	9.83± 0.09^{b}	10.39± 0.47^{b}	7.14± 0.18^{a}	1.53± 0.09^{a}
B	34.00± 0.27^{a}	12.75± 0.11^{c}	8.44± 0.16^{a}	6.94± 0.11^{a}	3.57± 0.05^{b}
CA	28.00± 0.19^{a}	7.75± 0.12^{a}	11.26± 0.16^{b}	5.48± 0.13^{a}	4.37± 0.03^{b}
D-6					
R	48.50± 0.27^{b}	21.63± 0.19^{c}	12.65± 0.11^{c}	4.19± 0.05^{c}	2.46± 0.11^{b}
B	36.50± 0.35^{a}	11.75± 0.15^{a}	3.46± 0.09^{a}	7.71± 0.11^{d}	0.27± 0.01^{a}
CA	67.50± 0.17^{c}	23.13± 0.17^{d}	12.47±0.11^{c}	0.73± 0.01^{a}	2.15± 0.04^{b}
D-9					
R	36.50± 0.41^{b}	10.50± 0.09^{c}	10.05± 0.11^{c}	0.873±0.02	n.d
B	24.00± 0.11^{a}	20.75± 0.17^{d}	3.29± 0.09^{a}	n.d	n.d
CA	56.00± 0.41^{c}	5.75± 0.11^{a}	12.47± 0.08^{c}	n.d	n.d

* Means with the same letter between the treatments are not significantly different at P≤0.05 by DMRT. **R-control raw; B-blanched; CA-1% Citric acid+ascorbic acid

The effect of minimal processing of pumpkin and squash are show in Table 9-b. The decrease in phenolics in case of control raw could be due to browning reactions where oxidation of polyphenols occurs. In rest of the samples, browning was somewhat checked due to blanching and antibrowning agent treatments. Again, the increase in phenolics with storage could be the result of processing induced damage (Babic et al., 1993). Moreover, phenolic compounds mainly

the bound forms remain in complex form with protein and carbohydrates in the food matrix. During storage, number of biochemical and microbial induced changes occur resulting in breakdown of these matrices that facilitates the release of phenolics into the extracting solvent medium. Again, an increase phenolic and flavonoid values doesn't always lead to an increased antioxidant activity because different phenolic acid has got different antioxidant potential depending on their structural conformations. Due to processing treatments, biochemical and microbial induced changes, the native phenolic structure gets altered and this in turn changes the free radical susceptibility and quenching activity. To ascertain the exact mechanism further study of the individual phenolic compounds will be required to determine their antioxidant behavior. Therefore, from the above results it can be inferred that during minimal processing treatment increase in phenolic content was observed in all the selected vegetables until 6th day of storage except in some cases. However, the overall antioxidant activity of the minimal processed samples decreased with the increase in duration of storage.

Table 9 (b) Changes in phytochemicals and antioxidant activity in minimally processed pumpkin and squash

Samples	TPC (mgGAE/100g)	TFC (mgQE/100g)	FRAP (uM/100g)	DPPH (%)	MCC (%)
Pumpkin					
D-0					
R	32.00±0.11^{b}	8.00±0.06^{b}	95.29±0.23^{b}	2.20±0.15^{a}	6.82±0.11^{a}
B	28.00±0.17^{a}	6.88±0.03^{a}	46.78±0.16^{a}	3.39±0.23^{b}	6.91±0.16^{a}
CA	65.00±0.09^{c}	6.75±0.10^{a}	93.55±0.11^{b}	5.63±0.18^{c}	14.04±0.12^{b}
D-3					
R	25.50±0.12^{a}	3.50±0.09^{a}	34.65±0.23^{a}	4.39±0.10^{c}	4.17±0.08^{a}
B	25.50±0.18^{a}	4.63±0.03^{b}	55.44±0.29^{b}	1.04±0.03^{a}	6.99±0.27^{b}
CA	57.00±0.23^{b}	6.38±0.13^{c}	69.30±0.18^{c}	2.25±0.07^{b}	10.74±0.08^{c}
D-6					
R	20.00±0.09^{b}	4.25±0.10^{a}	24.26±0.10^{b}	19.63±0.11^{b}	7.71±0.03^{b}
B	18.00±0.11^{a}	4.37±0.15^{a}	12.13±0.08^{a}	18.55±0.13^{b}	3.11±0.09^{a}
CA	48.000.13^{c}	4.13±0.07^{a}	69.30±0.23^{c}	16.11±0.09^{a}	2.85±0.06^{a}
D-9					
R	18.50±0.10^{a}	4.88±0.11^{c}	8.67±0.07^{a}	17.43±0.15^{a}	n.d
B	16.50±0.07^{a}	4.00±b0.0^{a}	15.59±0.13^{b}	16.25±0.21^{a}	1.25±0.02^{a}
CA	41.00±0.23^{b}	3.63±0.04^{b}	24.55±0.15^{c}	20.42±0.09^{b}	3.26±0.06^{b}
Squash					
D-0					
R	13.00±0.10^{a}	4.38±0.10^{a}	32.92±0.29^{a}	4.22±0.17^{c}	0.59±0.03^{a}

B	19.00±0.13^{b}	4.75±0.14^{a}	19.06±0.12^{a}	1.35±0.02^{a}	1.29±0.13^{a}
CA	50.50±0.21^{c}	4.88±0.21^{a}	76.23±0.17^{c}	3.17±0.10^{b}	5.48±0.21^{b}
D-3					
R	14.50±0.10^{c}	3.38±0.09^{c}	5.19±0.06^{a}	2.46±0.03^{a}	8.60±0.22^{b}
B	12.50±0.08^{b}	2.75±0.05^{b}	15.59±0.09^{b}	3.39±0.07^{b}	2.89±0.10^{a}
CA	9.50±0.04^{a}	1.38±0.03^{a}	39.85±0.16^{c}	2.63±0.07^{a}	2.17±0.09^{a}
D-6					
R	13.50±0.01^{b}	3.12±0.10^{b}	8.66±0.10^{a}	17.87±0.13^{b}	65.44±0.23^{b}
B	12.50±0.13^{a}	2.75±0.21^{a}	3.46±0.06^{a}	14.11±0.10^{a}	4.78±0.11^{a}
CA	38.00±0.07^{c}	2.62±0.11^{a}	43.31±0.08^{b}	19.23±0.18^{c}	3.59±0.14^{a}
D-9					
R	15.00±0.10^{b}	2.00±0.06^{a}	6.93±0.11^{a}	0.87±0.02^{a}	n.d.
B	11.00±0.04^{a}	2.13±0.4^{a}	19.06±0.17^{b}	14.11±0.09^{b}	1.89±0.05^{a}
CA	34.50±0.12^{c}	2.88±0.25^{b}	19.06±0.05^{b}	18.93±0.11^{c}	4.94±0.13^{b}

* Means with the same letter between the treatments are not significantly different at P≤0.05 by DMRT.

**R-control raw; B-blanched; CA-1% Citric acid+ascorbic acid

Part C: To measure the antioxidant capacity in fresh and processed viz. pasteurized and dried with different methods in fruits of Assam.

(i). Phytochemicals and antioxidant activity of the selected fresh untreated fruits

The following fourteen fresh fruits acetone extracts were studied for their phytochemical and antioxidant activity as shown in the Table 10. The highest TPC was observed in Black jamun followed by *Litchi*, *Bogi jamun* , *Amla* and *Bael*. The lowest value was exhibited by Watermelon (28 mgGAE/100g) and Pineapple (32 mgGAE/100g). In case of TFC, *Bael* showed highest value (331.33 mgQE/100g) followed by *Amla*. The lowest value was shown by *Bhimkal* (4.75 mgQE/100g) and pineapple (2.00 mgQE/100g). Similarly, *Bael*, *Amla*, Gauava, *Hogplum* and Carambola showed good ferric reducing antioxidant potential and radical scavenging activities compared to the rest of the studied fruits. The MCC value was highest in *Bael* (69.00%) followed by *Poniol* (18.65%) and Carambola (15.95%). Therefore, out of the following selected fruits, maximum of them exhibited good phytochemical properties.

Usually high antioxidant activity could be correlated to high phenolic content but in some cases this doesn't follow the same rule. Certain phenolics have a higher redox potential than that of other phenolics and therefore can exhibit independent results irrespective of their total phenolic content. Therefore, individual characterisation and identification of the phenolic compounds of the selected fruits are required to understand the pattern of antioxidant activity showed by them. The high flavonoid content in both poniol and black jamun could be due to the presence of anthocyanin pigment which is a derivative of anthocyanidins, a subgroup of flavonoid having good antioxidant property and in Bael due to the presence of quercetin in abundance. Therefore,

the selected fruits could be a naturally good source of phytochemicals and should be included in the diet more often for their health promoting properties.

Table.10 Phytochemicals and antioxidant activity of the selected fresh untreated fruits (fresh weight)

Name	TPC (mgGAE/100g)	TFC (mg/100g)	FRAP (μM/100g)	DPPH (%)	MCC (%)
Bogi jamun	2255.00± 0.45	18.85± 0.12	2180.55± 0.19	58.31± 0.27	6.16± 0.13
Litchi	2525.00± 0.12	13.13± 0.13	1581.60± 0.13	94.12± 0.19	8.06± 0.09
Poniol	377.00± 0.45	36.66±0.38	3288.28±0.46	91.97±0.39	18.65±0.27
Bael	866.67±0.47	331.33±0.33	6909.72±0.38	92.82±0.41	69.02±0.31
Bhimkal	61.00± 0.22	4.75±0.12	620.00±0.31	10.44±0.11	14.11±0.13
Amla	1923.00±0.26	152.25±0.23	6897.57±0.29	97.17±0.15	10.26±0.09
Olive	68.00±0.19	30.50±0.21	654.51±0.38	43.97±0.19	9.93±0.11
Leteku	305.50±0.28	43.00±0.19	2128.47±0.42	49.12±0.22	11.54±0.17
Guava	459.00±0.31	36.25±0.13	5263.89±0.19	93.78±0.16	7.43±0.24
Hogplum	658.50±0.13	65.63±0.11	4836.81±0.17	92.19±0.23	4.01±0.11
Carambola	652.50±0.11	29.75±0.17	4468.75±0.23	62.33±0.19	15.95±0.29
Pineapple	32.00±0.09	2.00±0.09	246.53±0.31	12.30±0.13	6.85±0.21
Watermelon	28.00±0.12	11.25±0.11	864.58±0.27	25.93±0.19	7.55±0.17
Black jamun	7185.00±0.15	44.13±0.21	5149.31±0.19	96.92±0.21	1.97±0.12

Note: The results were given as mean ± S.D. of triplicates values.

(ii). Phytochemicals study of pasteurized fruit juices

The selected fruit juices after pasteurization were analyzed for the effect of heat treatment on phytochemical content viz. TPC, TFC, ascorbic acid and antioxidant activity (FRAP and DPPH). The fresh fruit juices are rich in TPC and antioxidant actitvities (Table 11 and 13). Fresh *carambola* showed the maximum TPC value (1450.00 mgGAE/100ml) followed by *litchi* (692.50 mgGAE/100 ml). Other fruits showed reasonably good TPC values (75-467 mgGAE/100 ml). Moreover, fresh *carambola* juices showed high FRAP value (10221.76 μM Fe (II)/100 ml) and DPPH activity (97.11%). The ascorbic acid was high in fresh pineapple juice (60.00 mg/100ml) followed by *carambola* juice (40.63 mg/100ml). However, it was observed that pasteurization caused statistically significant change in the total phenolic content and other parameters with some exceptions when subjected to paired t-test at 5% significance level. The

changes in TPC and TFC are positively or negatively significant depending on the type of fruit in consideration. A decreased TPC and TFC were observed in pineapple, *pani jamun, litchi* and watermelon. The percentage of decrease ranged from 1.97% to 13.57% for TPC and 27.40% to 72.42% for TFC (Table 1). The maximum drop in flavonoids was observed in watermelon. However, *black jamun* and *carambola* showed an increased TPC and TFC values on pasteurization. The range of increase was from 6.33% to 20.11% for TPC and 17.92% to 33.34% for TFC (Table1). In case of ascorbic acid content, a decrease was observed in all the pasteurized juices. The loss was percentage ranged from 10.26% to 57.97% (Table 12). The maximum decrease was observed in *pani jamun*, watermelon and *black jamun*.

The antioxidant activities of pineapple, *litchi, pani jamun* and watermelon showed significant decrease except in *pani jamun* where no change in DPPH was observed on heating. The percentage of decrease for FRAP ranged from 2.83 % to 24.65% and 2.63 % to 37.65% for DPPH activity (Table 13). But, like reported in case of TPC and TFC values, *black jamun* and carambola juices showed significant increase in FRAP and DPPH activity values. The percentage of increase ranged from 0.092% to 27.50%. Overall, phenolics, flavonoids and antioxidant activity of watermelon and *pani jamun* were comparatively more susceptible to heat treatment.

The decrease in phytochemicals and antioxidant activity in some cases could be due to destruction of heat labile phenolic compounds and ascorbic acid present in the juices (Cortes et al., 2008). But, increased phenolic content in some pasteurized juices could be due to biochemical reactions that could have occurred during heat processing which led to the release of bound phenolics from the fruit matrix and also formation of new phenolic compounds by structural rearrangement (Rechkemmer *et al.*, 2007). Pasteurization might have caused significant effects on cell membranes or in phenolic complexes with other compounds, releasing some free phenolic acids or flavonoids (Scalzo et al., 2004). Heat might have also inactivated the polyphenol oxidase, preventing further loss of phenolic compounds. Moreover, *black jamun* and carambola contains proanthocyanidins which are quite stable to heat.

But mainly, the increase or decrease in phenolic content depends on the overall composition and types of individual phenolic acid present in maximum in the concerned fruit

juice. On heating phenolic compounds has a tendency to undergo some kind of structural rearrangement that could lead to either increased or decreased antioxidant activities.

Table 11. Changes in TPC & TFC in untreated and pasteurized juice

Sample name	Total Phenolic Content [mgGAE/100ml]			Total Flavonoid Content[mgQE/100ml]		
	Untreated juice	Pasteurized juice	% (decrease/ increase)	Untreated juice	Pasteurized juice	% (decrease/ increase)
Pineapple	467.00 ± 0.11 *	404.00± 0.27*	-13.00	120.50± 0.13*	69.75± 0.22*	-42.12
Litchi	692.50± 0.19*	598.50± 0.25*	-13.57	140.50± 0.19*	102.00± 0.28*	-27.4
Pani jamun	130.50± 0.23*	121.50± 0.19*	-6.89	69.75± 0.21*	44.63± 0.11*	-36.01
Watermelon	75.00± 0.15	76.51± 0.09	-1.97	59.50± 0.27*	16.38± 0.17*	-72.42
Black jamun	403.00± 0.22*	504.50± 0.17*	+20.11	58.38± 0.16*	71.13± 0.10*	+17.92
Carambola	1450.00± 0.35*	1548.00± 0.30*	+6.33	23.25± 0.11*	34.88± 0.06*	+33.34

Note: The results were given as mean ± S.D. of triplicates values. The * denotes statistically significant difference at P≤0.05 during Paired t-test.

Table 12. Changes in ascorbic acid in untreated and pasteurized juice

Sample name	Untreated juice (mg/100ml)	Pasteurized juice (mg/100ml)	% decrease/increase
Pineapple	60.00± 0.10*	44.00± 0.15*	-26.67
Litchi	18.75± 0.07*	13.75± 0.05*	-26.67
Pani jamun	10.42± 0.13*	4.38± 0.02*	-57.97
Watermelon	6.25± 0.09*	2.81± 0.02*	-55.04
Black jamun	5.63± 0.05*	3.13± 0.08*	-44.40
Carambola	40.63± 0.03*	36.46± 0.12*	-10.26

Note: The results were given as mean ± S.D. of triplicates values. The * denotes statistically significant difference at P≤0.05 during Paired t-test.

Table 13. Changes in FRAP & DPPH activity in untreated and pasteurized juice

Sample name	Ferric Reducing Antioxidant Potential [FRAP, µM Fe(II)/100g]			DPPH radical scavenging activity (%)		
	Untreated juice	Pasteurized juice	Percentage (decrease/ increase)	Untreated juice	Pasteurized juice	Percentage (decrease/ increase)
Pineapple	3373.18± 0.24*	2794.53± 0.33*	-17.15	43.65± 0.17*	41.80± 0.23*	-4.24
Litchi	5020.79± 0.09*	4878.73± 0.37*	-2.83	94.34± 0.11*	91.86± 0.35*	-2.63
Pani jamun	1474.36± 0.38*	1171.17± 0.21*	-20.56	63.34± 0.12	63.34± 0.09	No change
Watermelon	492.03± 0.31*	370.76± 0.19*	-24.65	40.77±0.09*	25.42± 0.18*	-37.65
Black jamun	4965.35± 0.28*	6848.82± 0.25*	+27.50	94.71± 0.15*	96.10± 0.21*	+1.44
Carambola	10221.76± 0.36*	10395.01± 0.28*	+1.67	97.11± 0.21	97.02± 0.17	+0.092

Note: The results were given as mean ± S.D. of triplicates values. The * denotes statistically significant difference at $P \leq 0.05$ during Paired t-test.

(iii). Phytochemical study of dried fruit using different drying methods

a) Spray drying

Four fruit juices from carambola, watermelon, pineapple and orange, respectively were spray dried with 20% maltodextrin as carrier agent (Table 14). The results showed a significant difference in phytochemical content between the untreated and spray dried fruit juice. In orange, an increase in TPC, TFC, FRAP and DPPH was observed although MCC showed a decrease in its value. While in watermelon, a decrease in all the phytochemical parameters were observed except in MCC where no change was obtained. The TPC, TFC and MCC values in carambola showed no significant difference on drying but increase in FRAP and DPPH was observed. However, in case of pineapple except in DPPH activity, TPC, TFC and MCC value decreased compared to untreated juice while change in FRAP was not significant.

The varied results could be due to the reaction of the various phenolic compounds present in the fruit juices to the heat applied during the drying process. Although, phenolic compounds are generally heat labile, individual phenolic compounds have different degree of tolerance to heat and the structural degradation and rearrangement hence in turn affect its content and activity. The conformational change in phenolics could either render them more soluble and extractable in the extracting solvent or make the less soluble thus affecting their quantification. For example, watermelon contains anthocyanin as the principal bioactive pigment and it is highly heat labile and hence on application of heat, a decrease in phytochemical content was observed. However, in carambola which is rich in proanthocyanidins which are relatively heat stable, on drying showed an enhanced FRAP and DPPH activity. Moreover, removal of moisture led to concentration of the bioactive compounds in some cases when compared with that of the raw samples. Hence, the change in phenolic content and antioxidant activity is depended upon individual phenolic acid constitutes and their susceptibility to heat and conformational changes.

Table 14. Phytochemical content and activity of spray dried fruit juice (dry basis)

Samples	Fresh juice	Spray dried juice
Orange		
TPC(**mgGAE/100g**)	79.64±0.12*	332.78±0.27*
TFC(**mgQE/100g**)	8.41±0.09*	34.16±0.21*
FRAP(**uM/100g**)	1220. 12±0.19*	1538.42±0.23*
DPPH (**%**)	59.97±0.17*	77.79±0.11*
MCC (**%**)	7.19±0.11*	4.34±0.18*
Watermelon		
TPC(**mgGAE/100g**)	97.92±0.23*	25.75±0.21*
TFC(**mgQE/100g**)	9.76±0.16*	2.14±0.05*
FRAP(**uM/100g**)	85.08±0.25*	18.08±0.11*
DPPH (**%**)	53.23±0.27	48.94±0.18
MCC (**%**)	7.62±0.11	7.55±0.10
Carambola		
TPC(**mgGAE/100g**)	644.65±0.22*	618.52±0.17*
TFC(**mgQE/100g**)	18.08±0.20	16.93±0.12
FRAP(**uM/100g**)	3155.57±0.14*	5210.17±0.19*
DPPH (**%**)	78.56±0.11*	92.24±0.27*
MCC (**%**)	9.40±0.16	11.54±0.22
Pineapple		
TPC(**mgGAE/100g**)	225.99±0.32*	149.32±0.28*
TFC(**mgQE/100g**)	7.77±0.11*	14.59±0.10*
FRAP(**uM/100g**)	679.38±0.29	627.99±0.23
DPPH (**%**)	59.97±0.27*	77.79±0.20*
MCC (**%**)	11.39±0.22*	2.71±0.03*

Note: The results were given as mean ± S.D. of triplicates values. * denotes statistically significant difference at $P \leq 0.05$ during Paired t-test.

b) Cabinet or tray, vacuum and freeze drying

Although application of heat to fruits generally leads to destruction of heat sensitive phytochemicals, many drying techniques had been used since time immemorial starting from sun drying to freeze drying, cryogenic drying and many more. In the present study application of cabinet or tray drying as well vacuum and freeze drying had both positive and negative effects on the phytochemical properties of the selected seven fruits (Fig 1-7).

Drying of pineapple showed a maximum decrease of TPC in vacuum dried samples followed by tray dried samples. TFC decrease was also highest in vacuum dried samples. The DPPH activity

was more or less retained in F/dried but MCC (%) was more in V/dried. In case of *Poniol*, highest TPC, TFC and FRAP values was observed in freeze dried sample followed by V/dried compared to raw fruit. Whereas, tray dried sample showed less values for TPC and TFC while there was no change in FRAP values. An increase in DPPH activity in all the dried samples was obtained but showed decreased values for metal chelation. Application of drying treatment to *Hogplum* destroyed the TPC and flavonoid content but reduction was less in freeze dried samples compared to vacuum and tray dried *Hogplum*. In case of FRAP values, decrease was more in vacuum dried samples. No major change in DPPH activity was observed in the dried samples. Moreover, the *hogplum* samples both raw fresh and dried one did not exhibit any metal chelation properties.

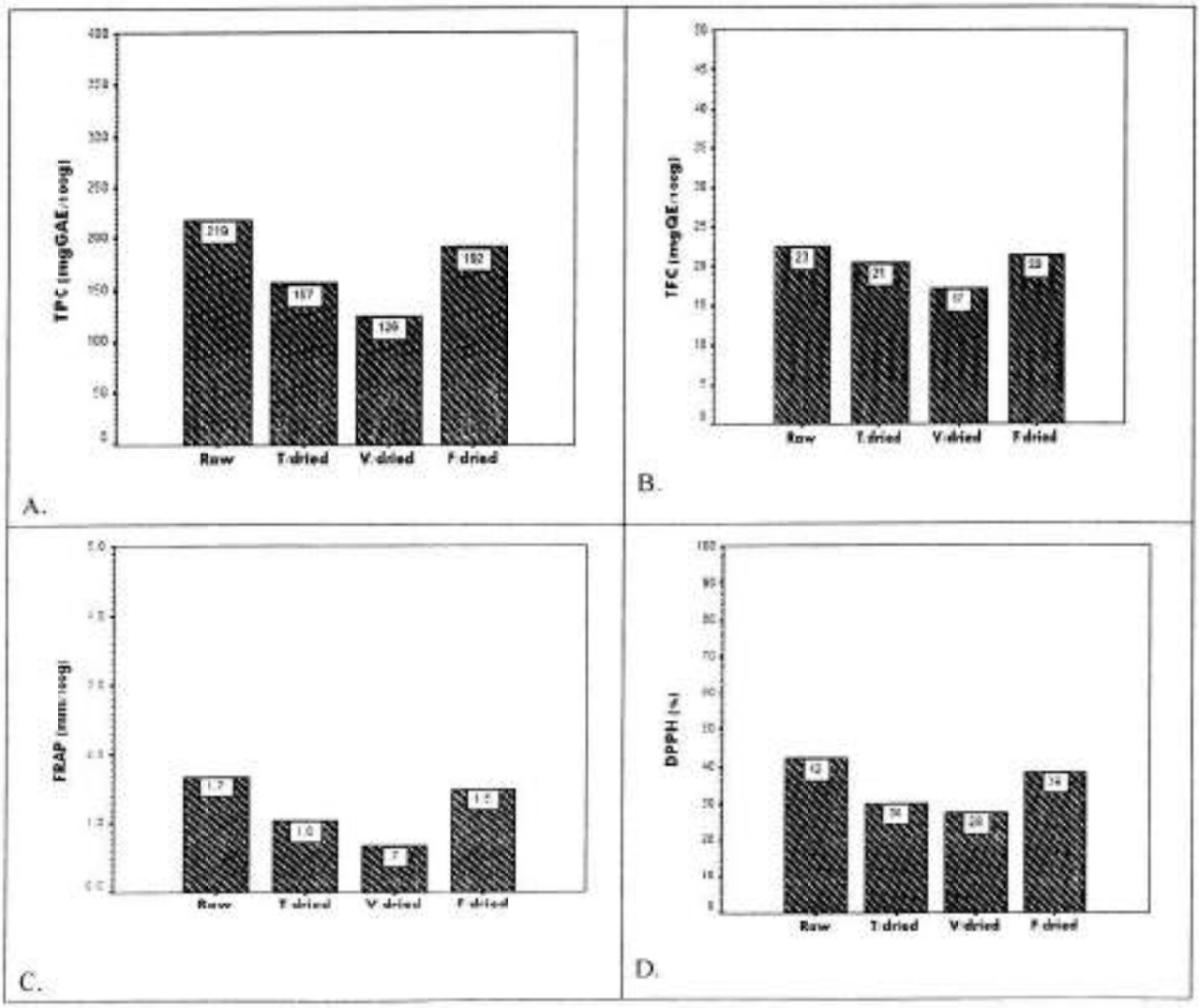
Drying of guava fruit caused a drastic decrease in TPC and TFC values in tray dried and vacuum dried samples compared to fresh raw guava. Similar is the case with FRAP values also. The DPPH activity in freeze dried sample almost showed activity comparable to that of fresh guava samples but major decrease was observed in tray dried samples. However, in MCC values the decrease was more in freeze dried guava. Overall, heating had a detrimental effect.

Upon drying the destruction of TPC was more rampant in black jamun in vacumm dried followed by tray drying. The decrease in TPC of freeze dried samples was 55.72%. Similarly, vacuum dried and tray dried samples showed a decreased TFC value compared to freeze dried jamun which did not showe any significant difference. Coming to FRAP data, all the three drying methods led to loss of antioxidant activity. Loss percentage is 86.45%-88.54%. In case of DPPH, no significant change in activity was obtained when compared with that of raw jamun. But, tray dried and vacuum dried samples didn't show any metal chelation capacity while freeze dried sample showed an increased activity.

The carambola fruit on drying caused detrimental effect on the TPC and TFC content. The FRAP value also correlated with the decreased phenolic and flavonoid content. However, radical scavenging values showed an increment upon drying. The MCC values showed a decreasing value, the maximum decrease was in tray dried and freeze dried samples. The TPC of *Leteku* fruit decreased on drying. The maximum destruction was in tray dried samples but vacuum dried *Leteku* showed maximum flavonoid destruction upon application of heat. Similarly, FRAP values also decreased on drying. But the DPPH activity in freeze dried sample increased while

tray dried sample showed a decreased value of 25.00% from 49.00% of raw fresh *Leteku*. The MCC value did not show a major difference between the fresh and dried fruits.

Application of heat in some cases could cleave the phenolic-sugar glycosidic bonds resulting in the formation of phenolic aglycons, which has high reactivity with Folin Ciocalteau reagent and thus leads to an increased value of total phenolic (Singleton et al., 1999). In case of freeze dried samples, if the fruit sample contains more lipophilic antioxidant compounds then bioactive property increases.(Marques et al., 2010). Overall, the behaviour of the phenolic compounds to a particular processing treatment depends on their type and composition and their interaction with the surrounding conditions.



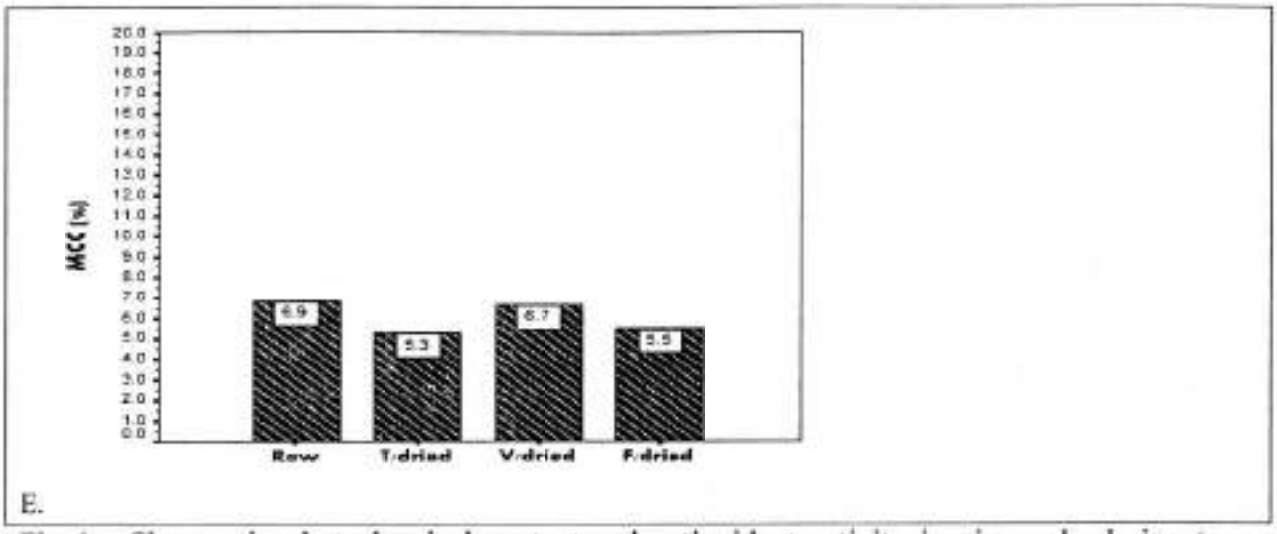
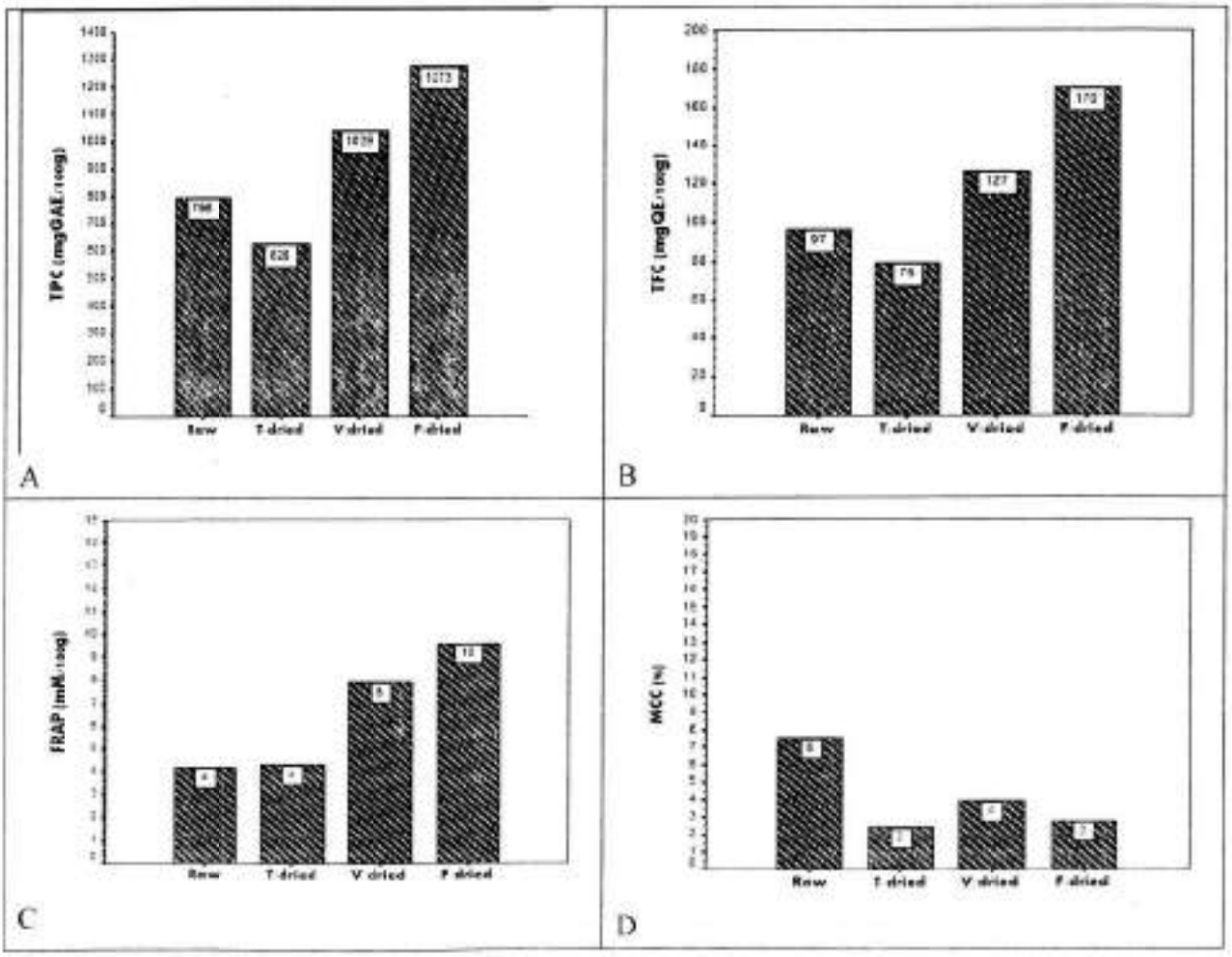


Fig 1 . Changes in phytochemical content and antioxidant activity in pineapple during tray, vacuum and freeze drying. A-Total phenolic content; B-Total flavonoid content; C-Ferric reducing antioxidant potential; D-DPPH radical scavenging activity; E- Metal chelation capacity.



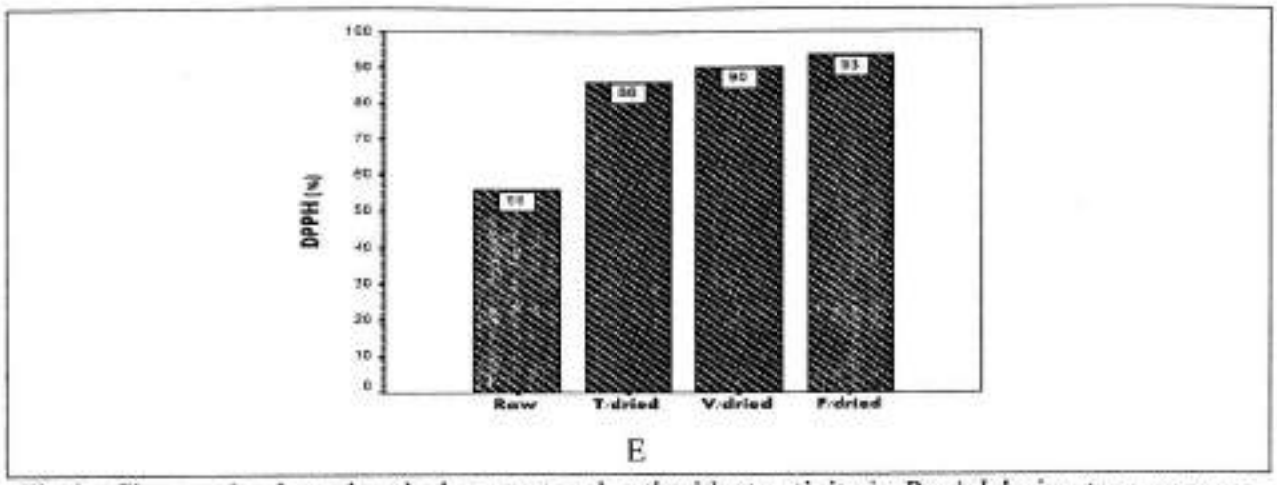
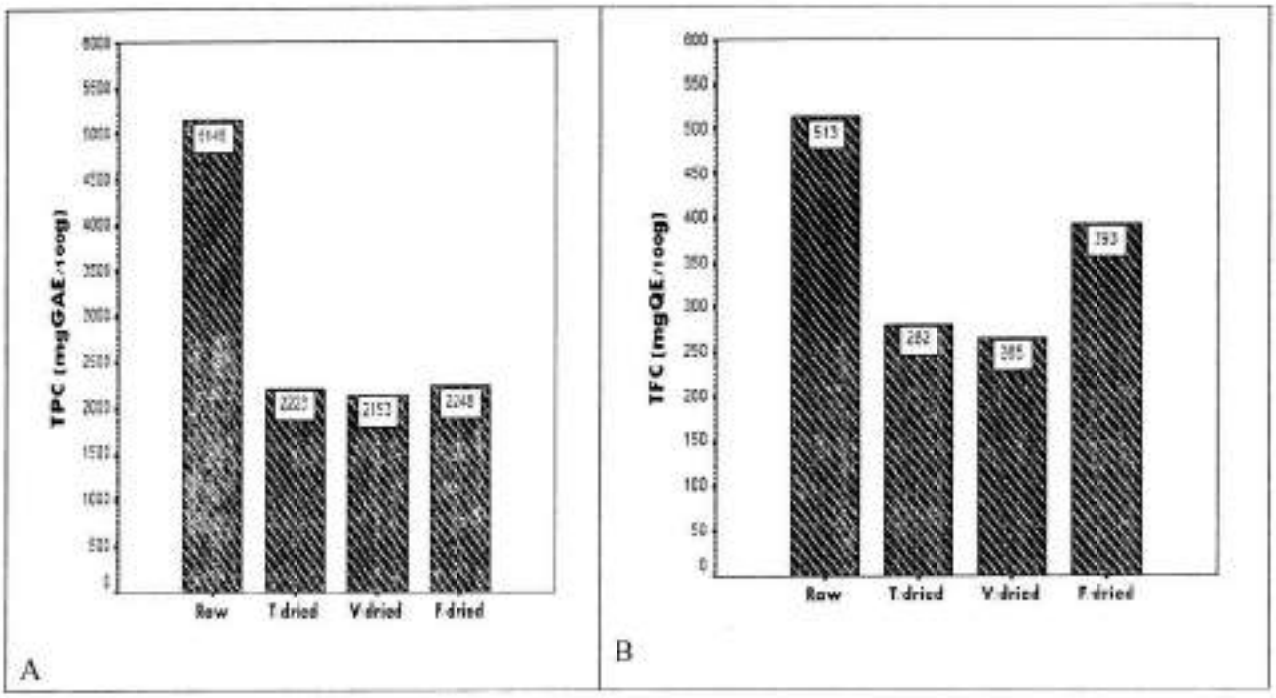


Fig 2 . Changes in phytochemical content and antioxidant activity in *Poniol* during tray, vacuum and freeze drying. A-Total phenolic content; B-Total flavonoid content; C-Ferric reducing antioxidant potential; D-DPPH radical scavenging activity; E- Metal chelation capacity.



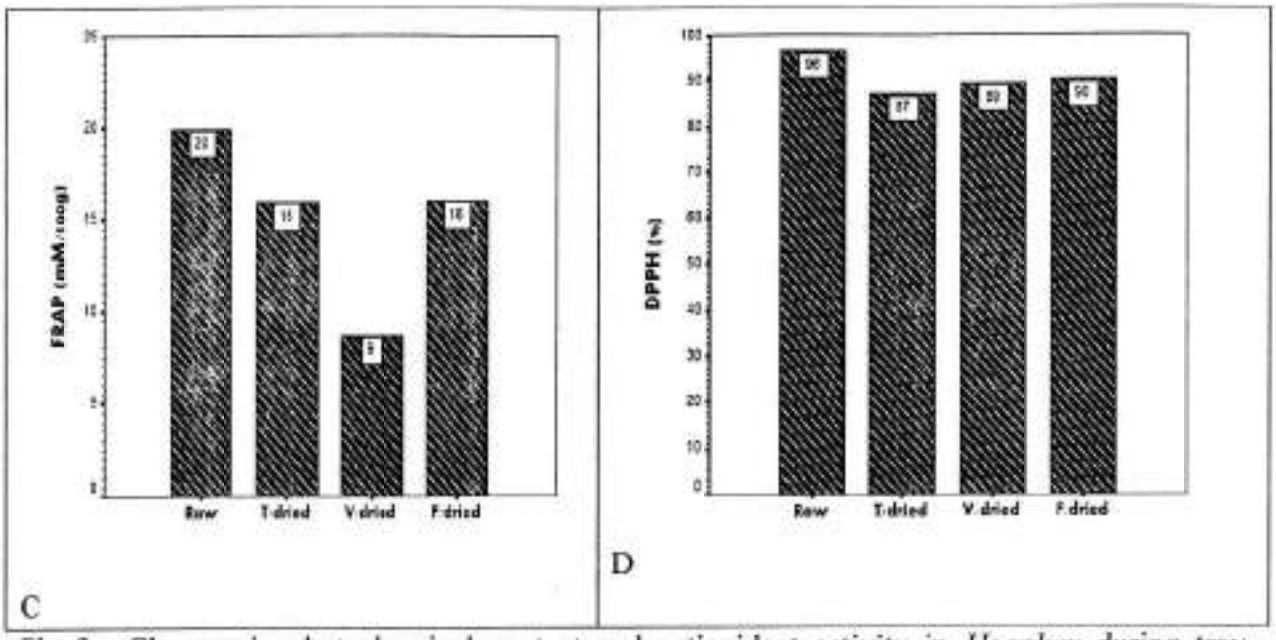
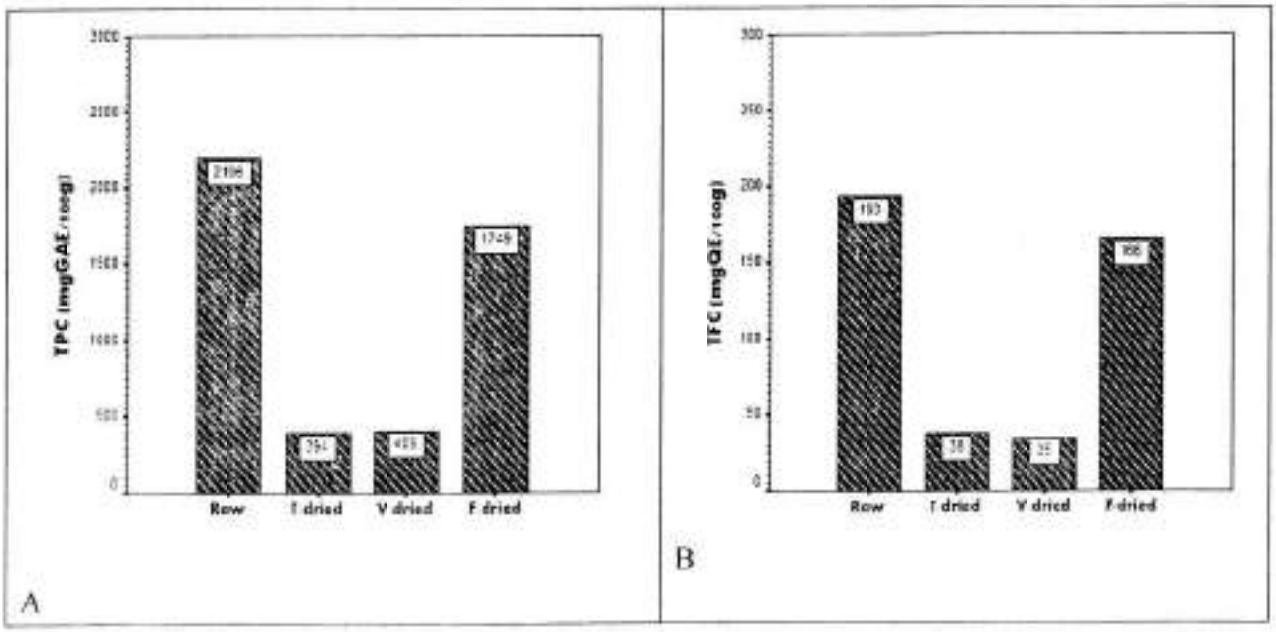


Fig 3 . Changes in phytochemical content and antioxidant activity in *Hogplum* during tray, vacuum and freeze drying. . A-Total phenolic content; B-Total flavonoid content; C-Ferric reducing antioxidant potential; D-DPPH radical scavenging activity.



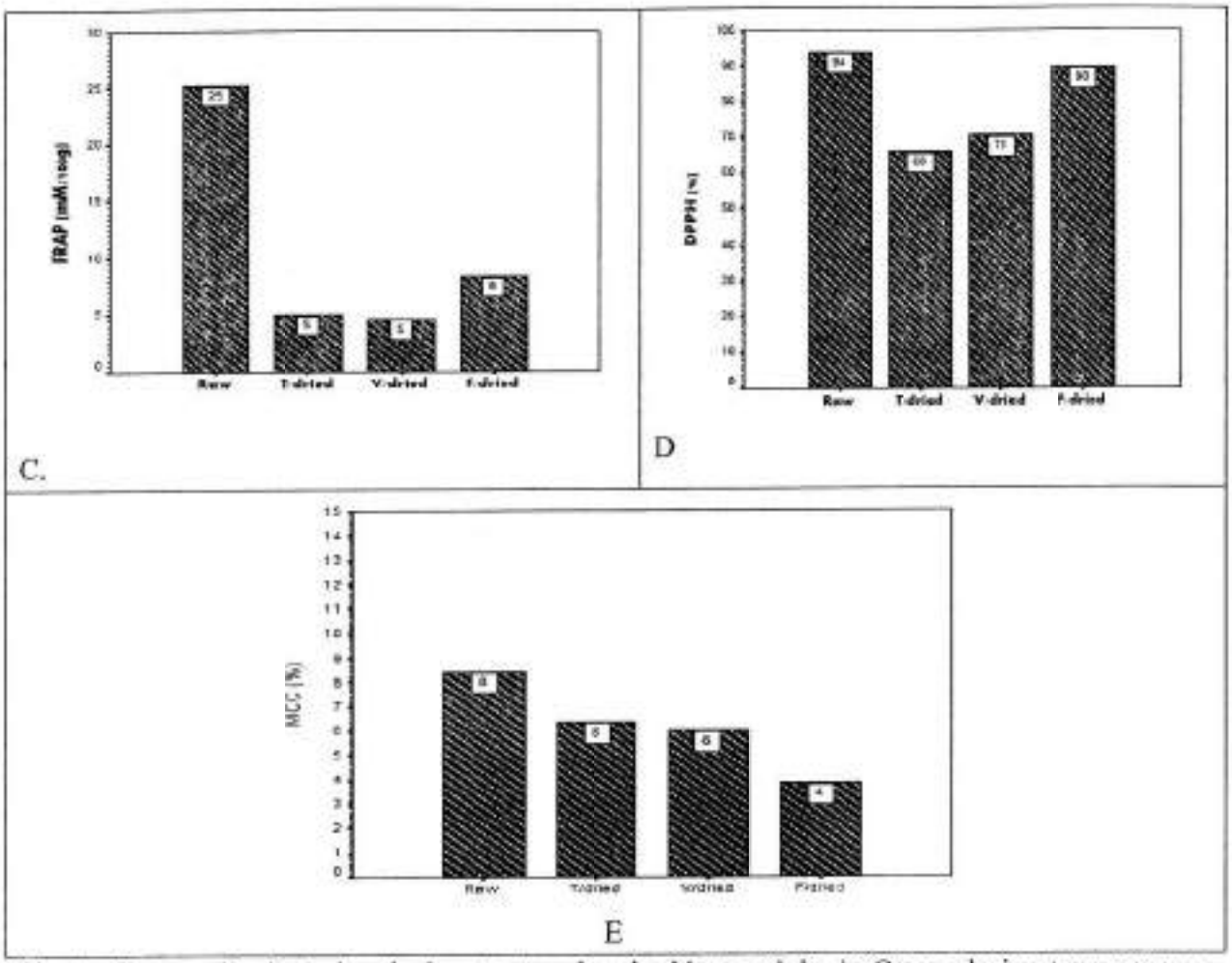
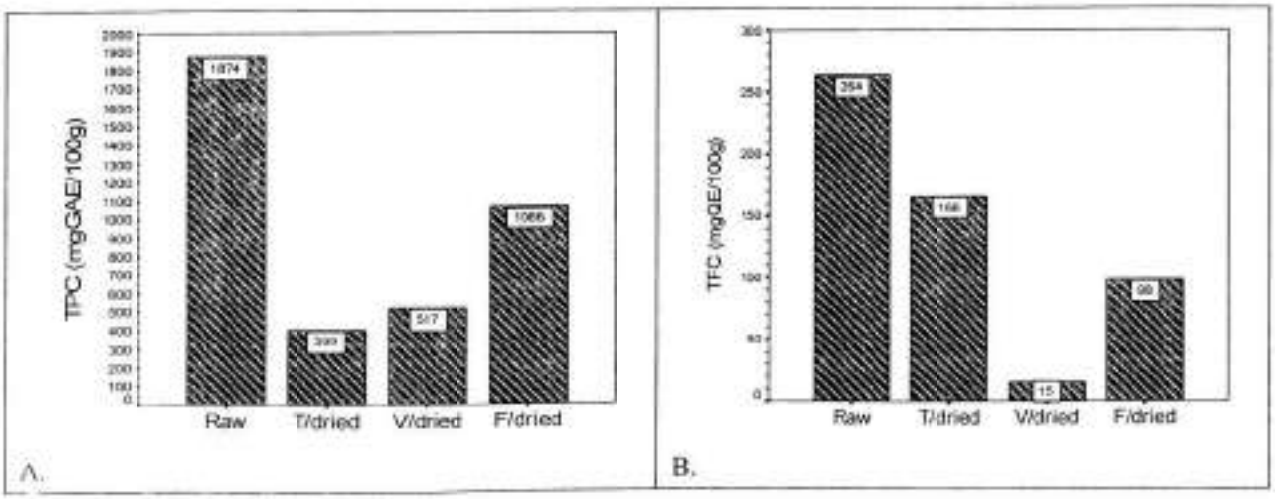


Fig 4 . Changes in phytochemical content and antioxidant activity in Guava during tray, vacuum and freeze drying. . A-Total phenolic content; B-Total flavonoid content; C-Ferric reducing antioxidant potential; D-DPPH radical scavenging activity; E- Metal chelation capacity.



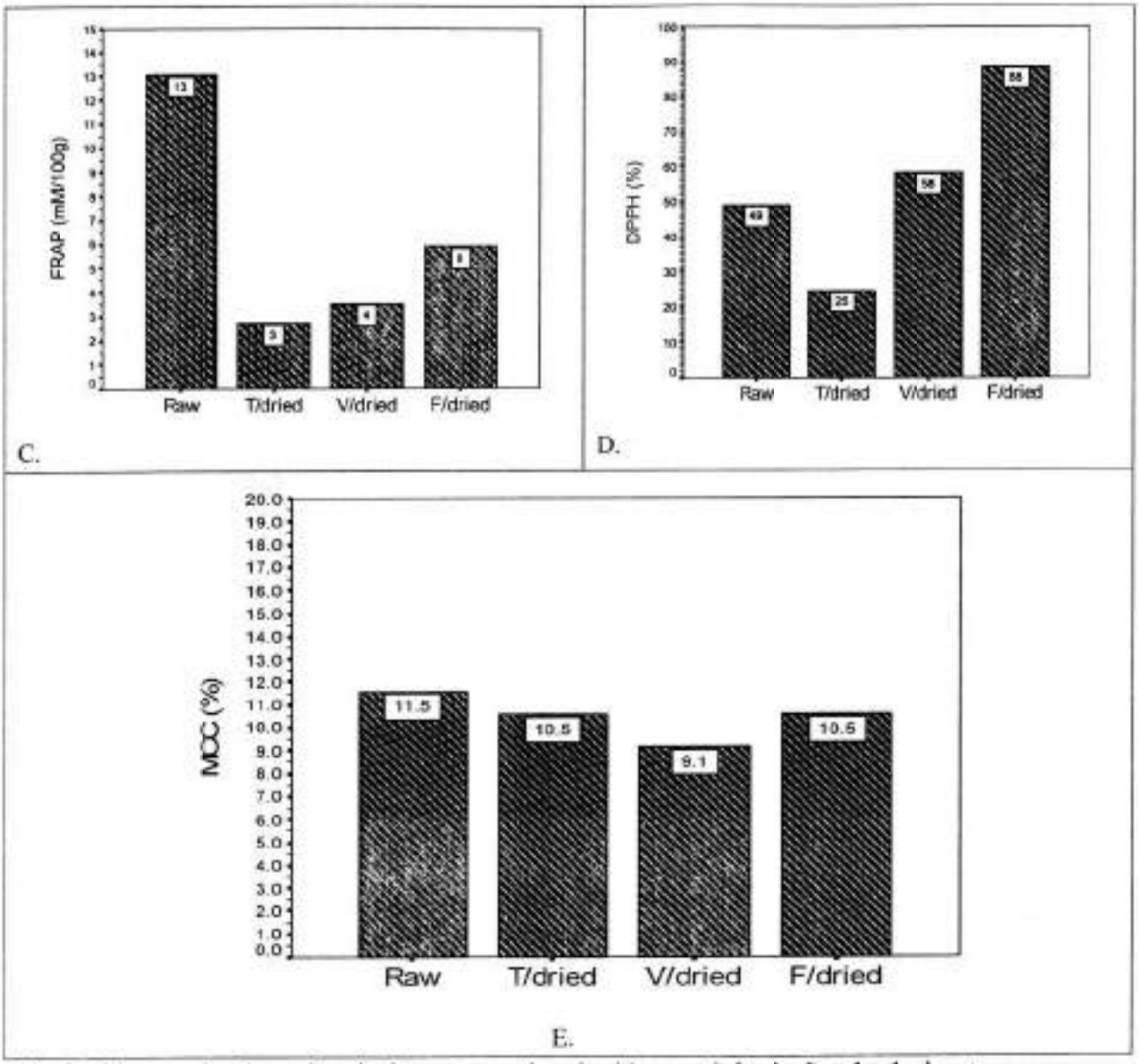
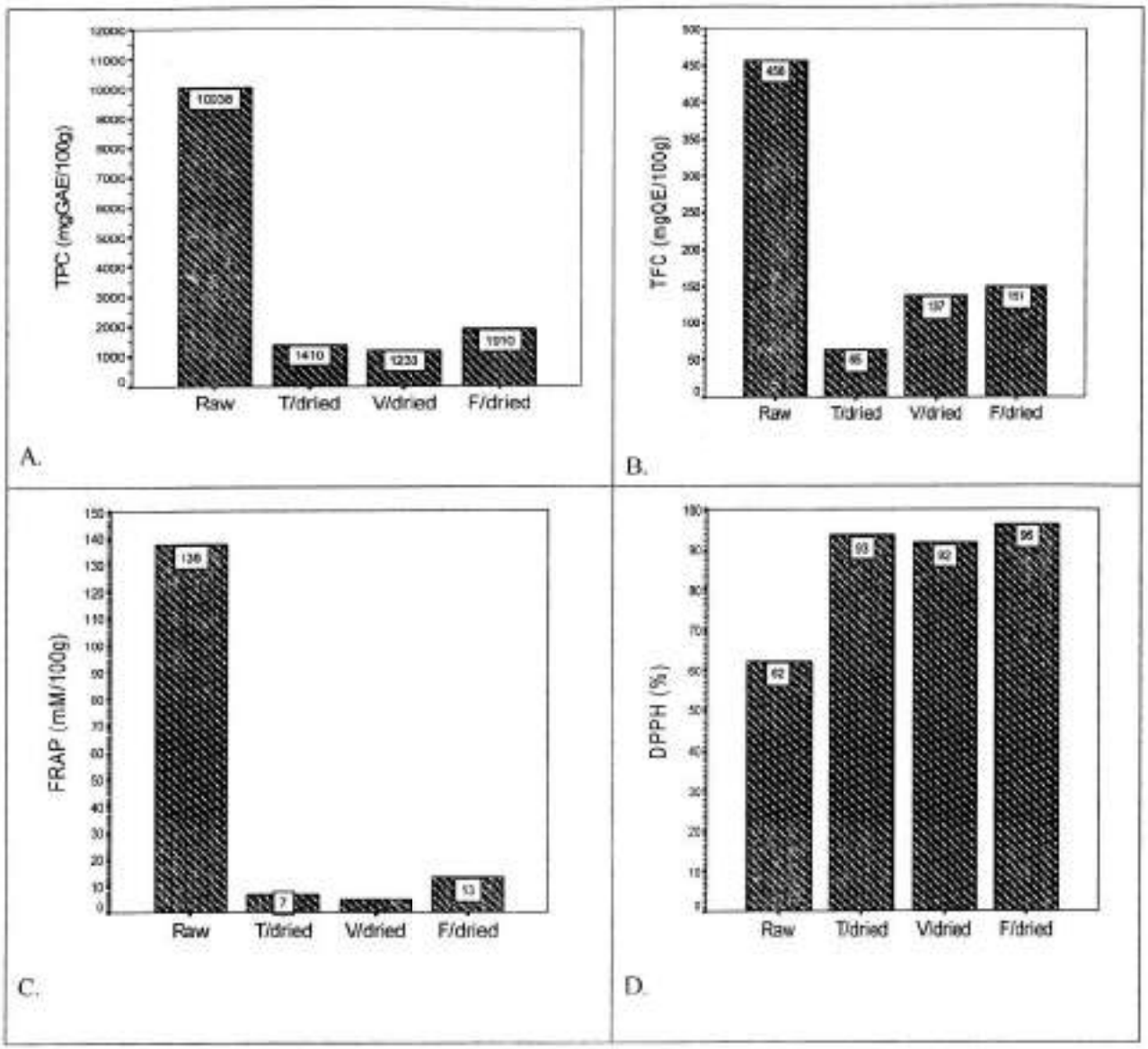


Fig 5 . Changes in phytochemical content and antioxidant activity in *Leteku* during tray, vacuum and freeze drying. . A-Total phenolic content; B-Total flavonoid content; C-Ferric reducing antioxidant potential; D-DPPH radical scavenging activity; E- Metal chelation capacity.


TPC (mgGAE/100g)
10036
1410
1233
1910
Raw
T/dried
V/dried
F/dried
A.
TFC (mgQE/100g)
458
65
137
151
Raw
T/dried
V/dried
F/dried
B.
FRAP (mM/100g)
138
7
13
Raw
T/dried
V/dried
F/dried
C.
DPPH (%)
62
93
92
96
Raw
T/dried
V/dried
F/dried
D.

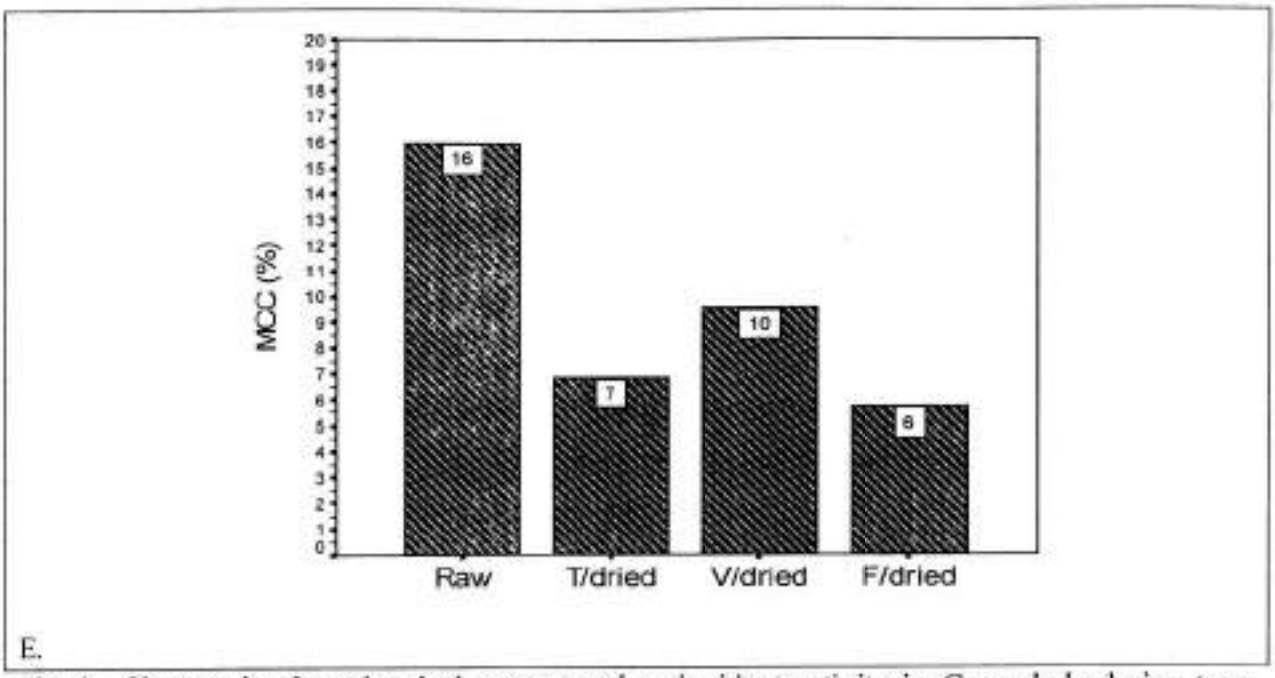
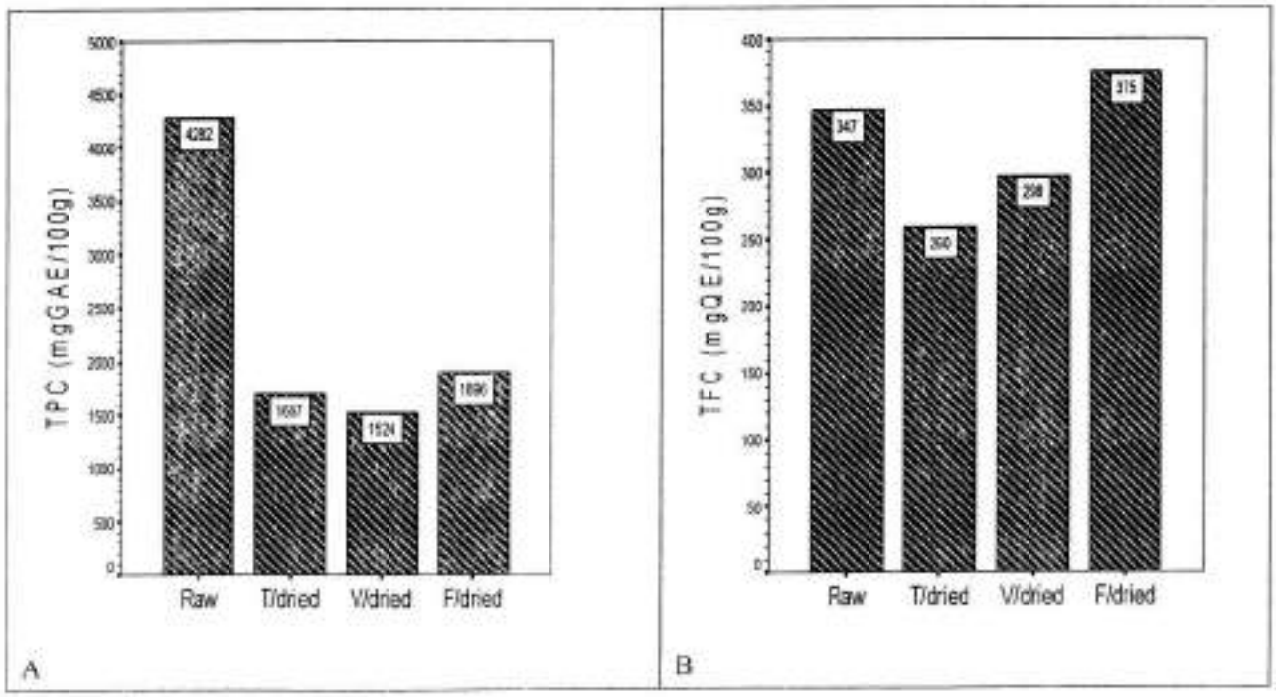


Fig 6 . Changes in phytochemical content and antioxidant activity in *Carambola* during tray, vacuum and freeze drying. . A-Total phenolic content; B-Total flavonoid content; C-Ferric reducing antioxidant potential; D-DPPH radical scavenging activity; E- Metal chelation capacity.



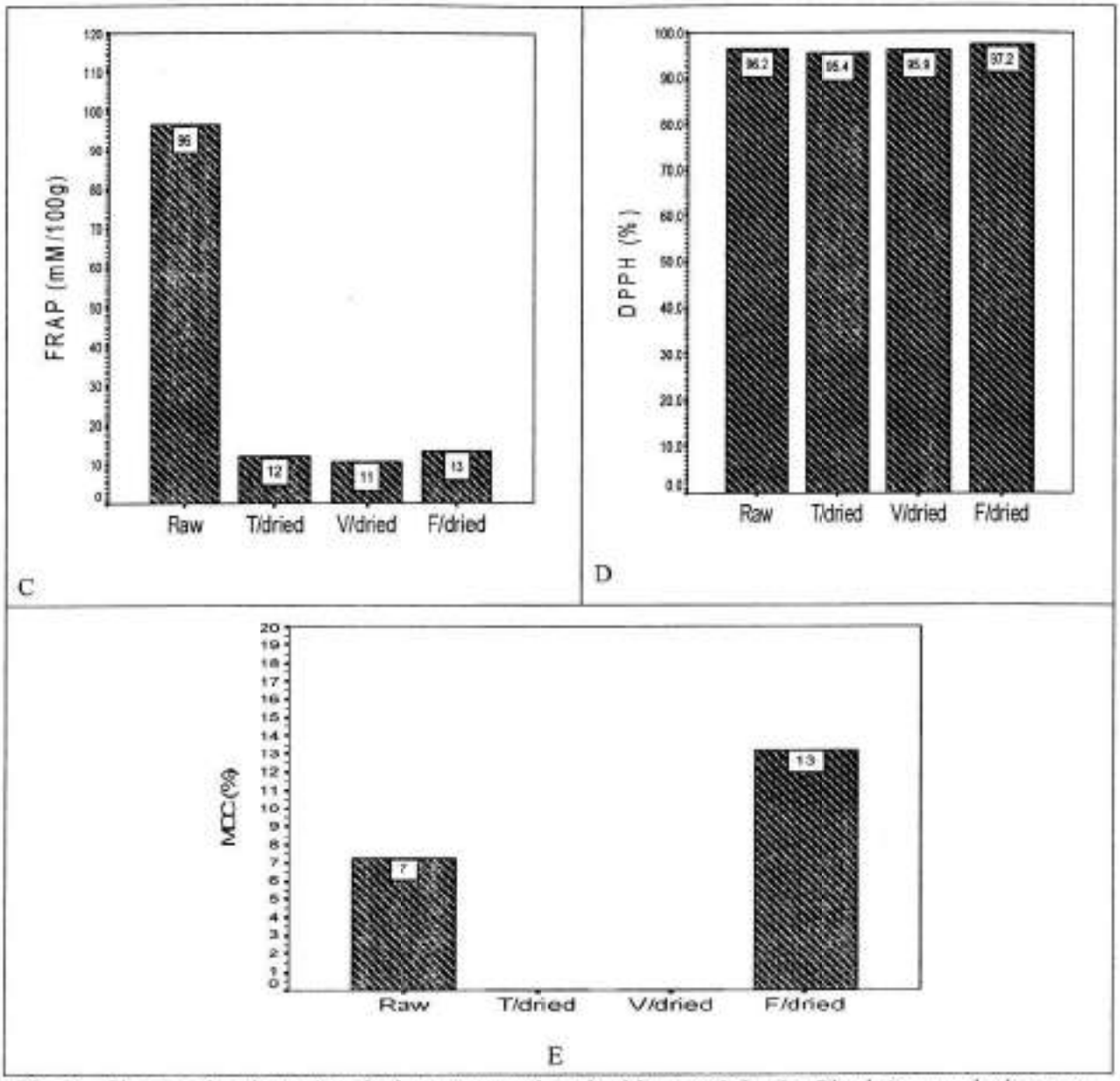


Fig 7 . Changes in phytochemical content and antioxidant activity in *Black jamun* during tray, vacuum and freeze drying. . A-Total phenolic content; B-Total flavonoid content; C-Ferric reducing antioxidant potential; D-DPPH radical scavenging activity; E- Metal chelation capacity.

Part D: To study the changes in phytochemicals in selected two fruits viz. litchi and black jamun stored at different temperatures for 6 days.

Two fruits viz. litchi and black jamun were studied for changes during storage at 3 different temperature conditions for 6 days. The results were given in the table 15. The fresh *Litchi* fruit on Day-0 showed a good TPC value (2525 mgGAE/100g), FRAP (1581.60 µM/100g), DPPH (94.12%) and MCC (8.06%). The TPC in Litchi at three temperature conditions showed varied

results during the six days of storage period. At the end of the 6th day, the room temperature (RT) samples showed a decrease of 18.6%; refrigerated temperature (RF) showed a decrease of 33.26% and deep freezed (DF) showed a decrease of 25.74%. The TFC at the end of 6th day showed no major change in their values. The FRAP values showed a slight decrease on the 6th day. However, theDPPH activity in RT samples declined to 66.00% followed by RF samples but the DF samples retained 93.73%. The RT samples showed a major drop in MCC value from 8.06 % on D-0 to 0.96% on D-6 while, RT and DF samples also showed a drop in values but it was less drastic compared to RF values.

In case of Black jamun, the storage study showed that RT samples got spoiled after D-2 due to action of microorganisms like mold and fungus. On D-2, the RT samples showed a drastic decrease in TPC, TFC and FRAP values. However, DPPH and MCC and Total anthocyanin content (TAC) was enhanced. The decreases in other two samples were less drastic. At the end of 6th day of study out of the remaining two samples i.e. RF and DF samples, the DF samples showed more TPC, MCC and TAC values whereas, RF samples showed more TFC and FRAP values. Both the samples retained more good DPPH activity.

Overall, the phytochemical content and activity decreased in all the samples regardless of the storage temperature conditions. This is because a fruit is a living biological system with continuous biochemical reactions and respirations occurring within it. Change in temperature only slows or retards the above processes but never stops the respiration and other enzymatic actions. Therefore, depending on the tolerance capacity of the concerned fruits to different temperature conditions, different value for phytochemical content and activity was observed.

Table 15. Phytochemicals in selected two fruits viz. Litchi and black jamun at three different storage temperatures

Samples	TPC (mgGAE/100g)	TFC (mgQE/100g)	FRAP (uM/100g)	DPPH (%)	MCC (%)	Total anthocyanin Content (mg/100g)
Litchi						
Fresh D-0	2525.00±0.37	13.13±0.23	1581.60±0.19	94.12±0.10	8.06±0.12	NA
D-2						
RT (25°C)	1940.00±0.22^a	15.13±0.10^a	1489.93±0.23^a	84.15±0.25^a	6.43±0.21^b	NA
Refrigeration	2145.00±0.29^a	54.13±0.26^c	1553.82±0.27^a	93.65±0.21^b	1.55±0.09^a	NA

(8°C)						
Deep freezing (-20°C)	4490.00±0.23^{b}	29.88±0.31^{b}	2638.89±0.29^{b}	94.31±0.19^{b}	7.69±0.09^{c}	NA
D-4						
RT (25°C)	2850.00±0.13^{b}	18.63±0.21^{b}	1678.82±0.26^{a}	78.15±0.19^{a}	6.36±0.03^{b}	NA
Refrigeration (8°C)	3360.00±0.12^{c}	21.00±0.07^{c}	2326.39±0.31^{b}	93.35±0.23^{b}	0.81±0.03^{a}	NA
Deep freezing (-20°C)	2495.00±0.19^{a}	18.00±0.09^{a}	1638.89±0.09^{a}	94.54±0.15^{b}	9.69±0.09^{c}	NA
D-6						
RT (25°C)	2055.00±0.23^{c}	14.50±0.11^{b}	1196.18±0.19^{a}	66.96±0.11^{a}	7.32±0.11^{c}	NA
Refrigeration (8°C)	1685.00±0.19^{a}	14.38±0.17^{b}	1362.85±0.17^{b}	87.58±0.18^{b}	0.96±0.10^{a}	NA
Deep freezing (-20°C)	1875.00±0.11^{b}	13.25±0.12^{a}	1147.57±0.29^{a}	93.73±0.23^{c}	5.99±0.18^{b}	NA
Black jamun						
D-0	7185.00±0.29	44.13±0.29	5149.31±0.35	96.92±0.29	1.97±0.07	15.58±0.25
D-2						
RT (25°C)	3170.00±0.11^{a}	11.13±0.11^{a}	3117.36±0.31^{a}	97.42±0.12^{a}	3.16±0.10^{a}	28.65±0.22^{b}
Refrigeration (8°C)	5965.00±0.17^{b}	38.75±0.19^{c}	5385.42±0.28^{b}	97.28±0.09^{a}	3.93±0.12^{b}	12.01±0.17^{a}
Deep freezing (-20°C)	6960.00±0.29^{c}	20.50±0.22^{b}	4420.14±0.19^{b}	97.38±0.11^{a}	2.74±0.15^{a}	14.33±0.19^{a}
D-4						
RT (25°C)	n.d	n.d	n.d	n.d	n.d	n.d
Refrigeration (8°C)	4535.00±0.32^{a}	37.00±0.23^{b}	3763.89±0.36^{a}	97.12±0.10^{a}	4.36±0.10^{b}	7.39±0.10^{b}
Deep freezing (-20°C)	6365.00±0.37^{b}	29.38±0.19^{a}	5519.09±0.29^{b}	97.42±0.09^{a}	2.91±0.14^{a}	5.57±0.09^{a}
D-6						
RT (25°C)	n.d	n.d	n.d	n.d	n.d	n.d
Refrigeration (8°C)	3690.00±0.19^{a}	26.13±0.22^{b}	5003.47±0.23^{b}	97.50±0.11^{a}	1.79±0.10^{a}	7.58±0.16^{b}
Deep freezing (-20°C)	6245.00±0.21^{b}	17.75±0.17^{a}	3317.71±0.13^{a}	97.12±0.09^{a}	2.82±0.13^{b}	3.97±0.13^{a}

RT means room temperature; n.d. means not determined

* * Means with the same letter within row are not significantly different at P≤0.05 by DMRT. Superscript of DMRT describes significant difference between the treatments

CONCLUSIONS

The results presented here clearly show that cooking can make the polyphenols and antioxidants of cooked food quite different from that of uncooked food. This is probably due to variety of effects like destruction, release and transformation of the phytochemicals. From the present study it was observed that the extraction efficiency of the solvents differed for different vegetables depending on the diversity of the phenolic compounds present. However, methanol, water and acetone have good extractability properties. Cooking enhanced the antioxidant activity of the selected vegetables than the raw forms in most of the cases. Overall, steaming was the most preferred method for cooking. But in case of cooked banana blossom, a decrease in flavonoid content was observed. Overall, antioxidant activity of the minimal processed samples decreased with the increase in duration of storage.

The selected fruits contain considerably good phenolic content and high antioxidant activities except in *Bhimkal* and pineapple where the content is lower compared to the rest of selected fruits. The highest phenolic content was observed in *Black jamun*. Similarly, *Bael* exhibited highest flavonoid content and FRAP value. Therefore, the selected fruits could be a naturally good source of phytochemicals and should be included in the diet more often for their health promoting properties.

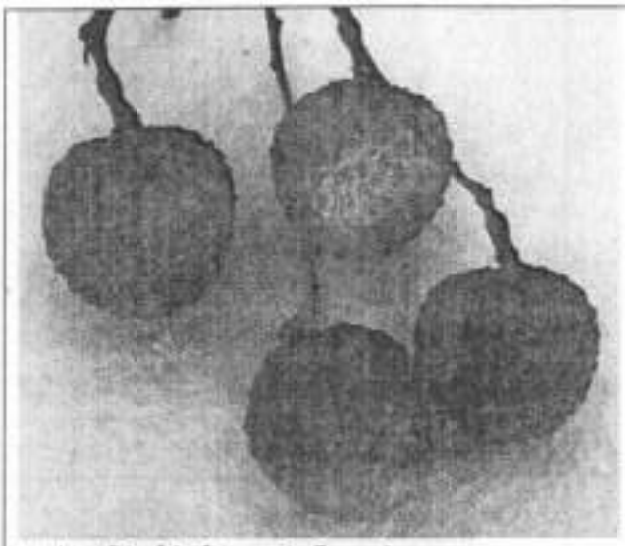
The pasteurization treatment had negative effect on the TPC, TFC and antioxidant activities in pineapple (*Ananas comosus*), watermelon (*Citrullus lanatus*), *pani jamun* (*Syzygium samarangense*) and *litchi* (*Litchi chinensis*) whereas carambola or star fruit (*Averrhoa carambola*) and *black jamun (Syzygium cumini)* showed an increasing trend. Overall, *carambola* fresh juice has better antioxidant properties which are further enhanced on pasteurization. Watermelon has low levels of antioxidant capacities. During spray drying a significant difference in phytochemical content between the untreated and spray dried fruit juice was observed. Application of cabinet or tray drying as well vacuum and freeze drying had both positive and negative effects on the phytochemical properties of the selected seven fruits. In case of storage study of fruits, the phytochemical content and activity decreased in all the samples regardless of the storage temperature conditions. This is because a fruit is a living biological system with continuous biochemical reactions and respirations occurring within it. Change in temperature only slows or retards the above processes but never stops the respiration and other enzymatic actions. Therefore, any kind of processing given to both fruits and vegetables is bound to cause an irreversible change in the nutritional, physical as well as chemical properties but in order to increase their palatability and availability as well as value addition, processing treatments are inevitable and unavoidable. Therefore, it dwells on us to decide the right and required type of processing treatment and also to develop more novel techniques that should be given to fruits and vegetables in order to achieve more palatability and increased shelf life but keeping in considerations their nutritional and health promoting properties.

REFERENCES

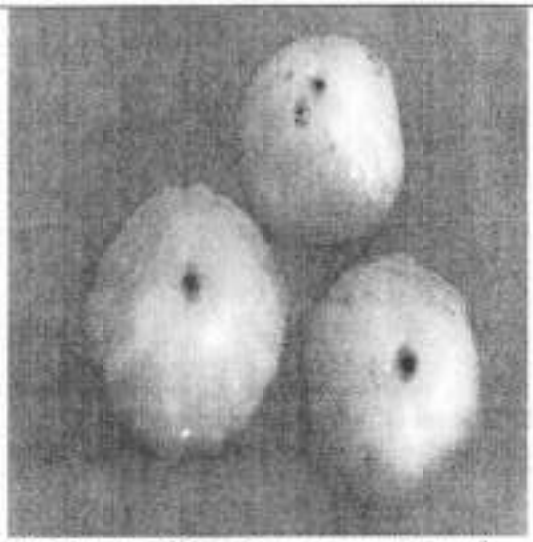
1. Atala, E., Vásquez, L., Speisky, H., Lissi, E., & López-Alarcón, C. (2009). Ascorbic acid contribution to ORAC values in berry extracts: An evaluation by the ORAC-pyrogallol red methodology. *Food Chemistry*, 113, 331-335.
2. Bernhardt, S., & Schlich, E. (2006). Impact of different cooking methods on food quality: Retention of lipophilic vitamins in fresh and frozen vegetables. *Journal of Food Engineering*, 77, 327-333.
3. Benzie, I. F. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "Antioxidant Power" the FRAP assay. *Analytical Biochemistry*, 239, 70-76.
4. Brand-Williams, W., Cuvelier, M.E. & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *Lebensmittel-Wissenschaft und Technology*, 28, 25–30.
5. Babic, I., Amiot, M. J., Nguyen-The, C., & Aubert, S. (1993a).Changes in phenolic content in fresh ready-to-use shredded carrots during storage. *Journal of Food Science*, 58(2), 351–356.
6. Carter, P. (1971). Spectrophotometric determination of serum iron at the submicrogram level with a new reagent – ferrozine. *Analytical Biochemistry*, 40, 450–458.
7. Chang, C.C., Yang, M.H., Wen, H.M. & Chern, J.C. (2002). Estimation of total flavonoid content in propolis by two complementary colorimetric methods. *Journal of Food Drug Analysis*, 10: 178-182.
8. Cortes, C., Esteve, M.J. & Frigola, A. (2008). Colour of orange juice treated by high intensity pulsed lectric fields during refrigerated storage and comparison with pasteurized juice. *Food control*, 19, 151-158.
9. Dinis, T. C. P., Madeira, V. M. C., & Almeida, L. M. (1994). Action of phenolic derivatives (acetaminophen, salicylate, and 5-aminosalicylate) as inhibitors of membrane lipid peroxidation and as peroxyl radical scavengers. *Archives of Biochemistry and Biophysics*, 315, 161–169.
10. Freed, M. (1996). Method of vitamin assay .Interscience Publication Inc., New York .
11. Giusti, M. M., & Wrolstad, R. E. (2001). Characterization and measurement of anthocyanins by UV–visible spectroscopy. In R. E. Wrolstad (Ed.), *Current Protocols in Food Analytical Chemistry* (1.2.1-13). New York: John Wiley and Sons.
12. Ismail, A., Marjan, Z., & Foong, C.W. (2004). Total antioxidant activity and phenolic content in selected vegetables. *Food Chemistry*, 87, 581-586.

13. Knekt, P., Kumpulainen, J., Jarvinen, R., Rissanen, H., Heliovaara, M., Reunanen, A., Halulinen, T., & Aromaa, A. (2002). Flavonoids intake and risk of chronic diseases. *American Journal of Clinical Nutrition*, 76,560-568.
14. Liu, S., Manson, J.E., Lee, I.M., Cole, S.R., Hennekens, C.H., Willet, W.C., & Burning, J.(200). Fruit and vegetable intake and risk of cardiovascular disease: The Women's Health Study. *American Journal of Clinical Nutrition*, 72, 922-928.
15. Manzocco, L., Calligaris, S., Masrocola, D., Nicoli, M.C., & Lerici, C.R. (2001). Review of non-enzymatic browning and antioxidant capacity in processed foods, *Trends in Food Science & Technology*, 11, pp. 340–346.
16. Nicoli, M.C., Anese, M., & Parpinel, M (1999). Influence of processing on the antioxidant properties of fruits and vegetables. *Trends in Food Science & Technology*, 10, 94-100.
17. Rechkemmer, G. (2007). Nutritional aspects from thermal processing of food: Potential health benefits and risks. In: G. Eisenbrand, K.H. Engel, W. Grunow, A. Hartwig, D. Knorr and I.B. Knudsen *et al.*, Editors, *Symposium*, Wiley-VCH Verlag GmbH & Co., KGaA, Weinheim.
18. Sukhwant, M.K., Harvinder, K., & Tejinder, G. (1992). Effect of cooking on fibre content of vegetables. *Journal of Food Science and Technology*, 29, 185-186.
19. Slinkard, S., & Singleton, V.L. (1977). Total phenol analysis: automation and comparison with manual methods. *American Journal of Enology and Viticulture*, 28, 49–55.
20. Scalzo,R.L., Jannoccart, T., Summa, C. and Morelli, R. and Rapisrda, P. (2004). Effect of thermal treatments on antioxidant and antiradical activity of blood orange juice. *Food Chemistry*. 85, 41-47.

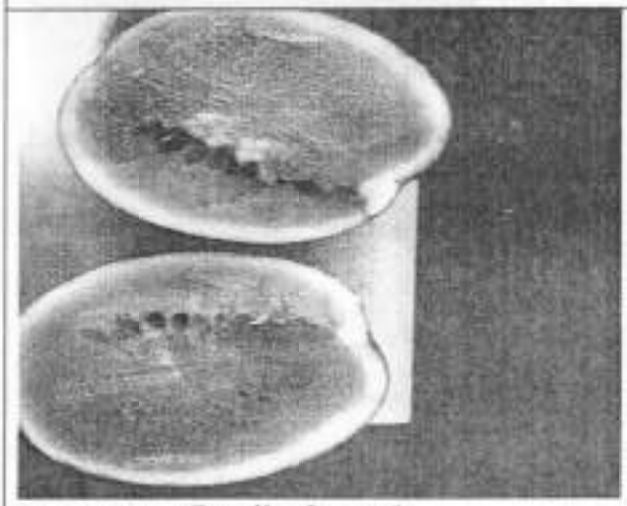
PICTURES OF SOME OF THE STUDIED FRUITS AND VEGETABLES



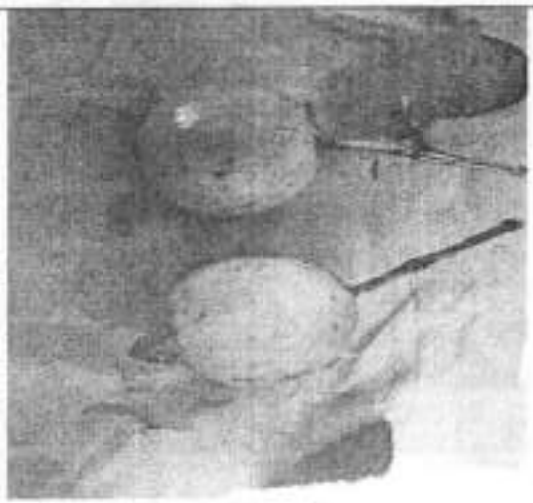
Litchi (*Litchi chinensis* Sonn.)



Pani jamun (*Syzygium samarangense*)



Watermelon (*Citrullus lanatus*)

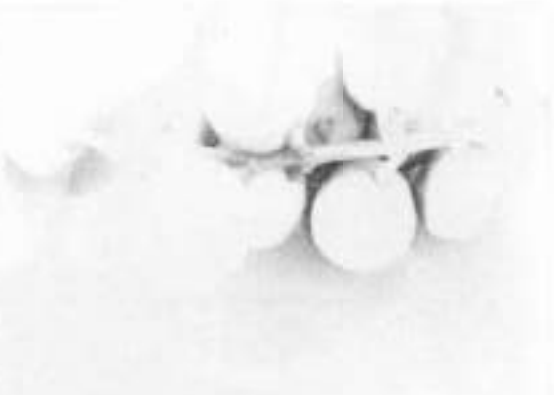


Guava (*Psidium guajava*)

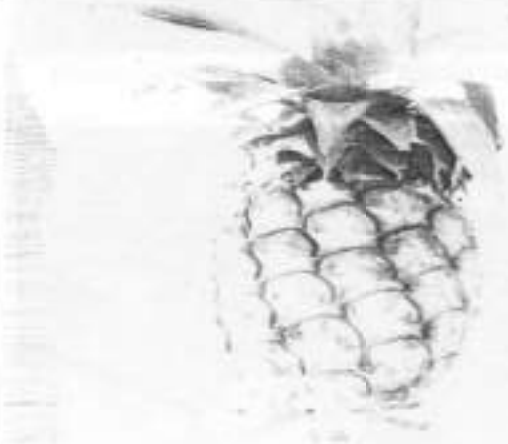
Carambola (*Averrhoa carambola*)

Bogi jamun (*Syzygium jambos*)

Black jamun *(Syzygium cumuni)*



Leteku (*Baccurea sapida*)



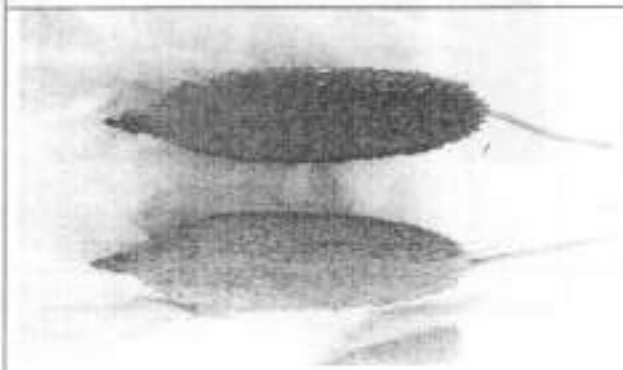
Pineapple *(Ananas comosus)*.

Poniol *(Flacourtia catafracta Roxb)*

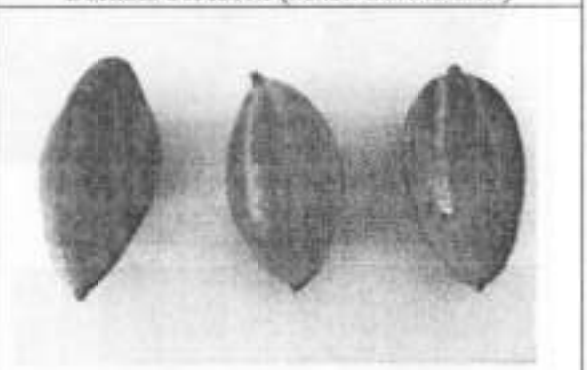
Hogplum *(Spondias pinnata)*

Beetroot (*Beta vulgaris*)

Banana blossom (*Musa balbisiana*)

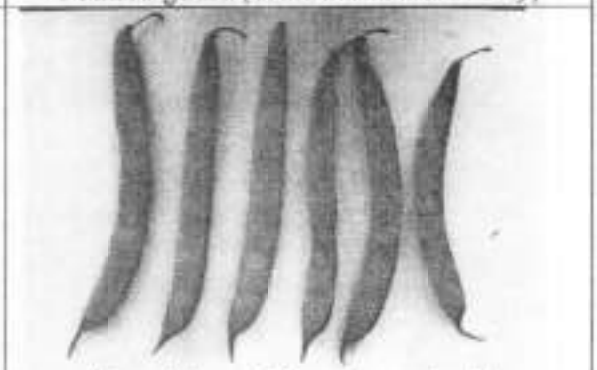


Teaslegourd *(Momordica dioica)*



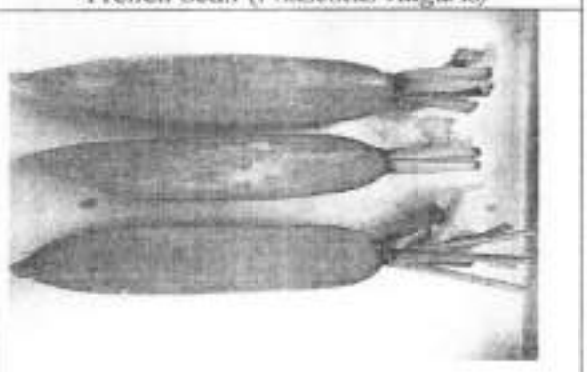
Pointed gourd *(Trichosanthes dioica)*,

Brinjal (*Solanum melongena)*

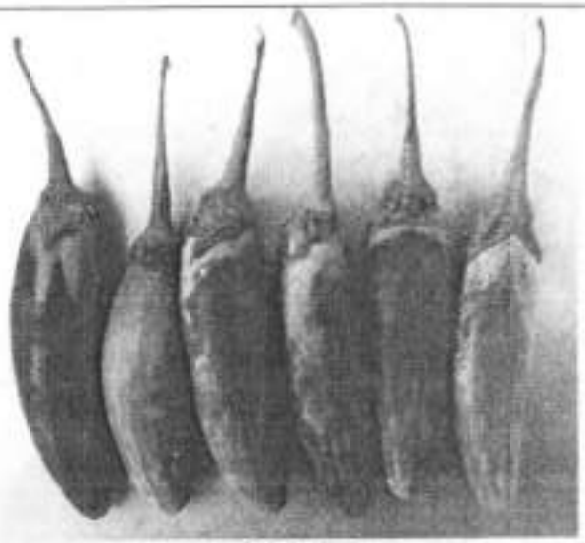


French bean (*Phaseolus vulgaris)*

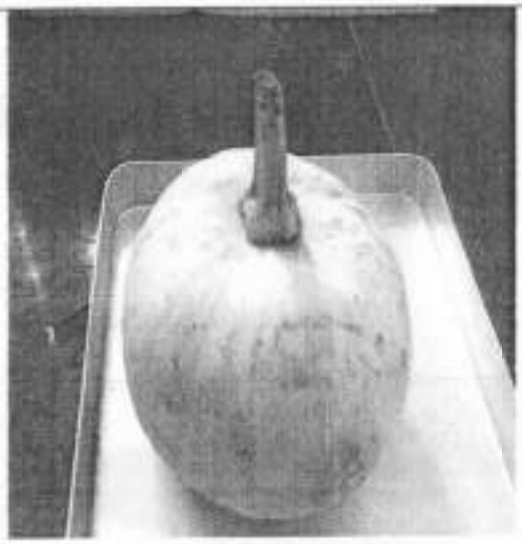
Ivy gourd (Coccinia grandis)



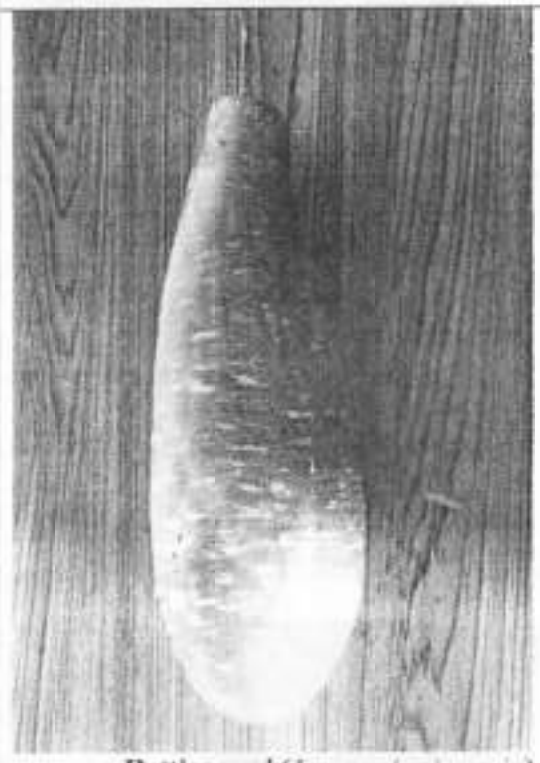
Radish (*Raphanus sativus*)



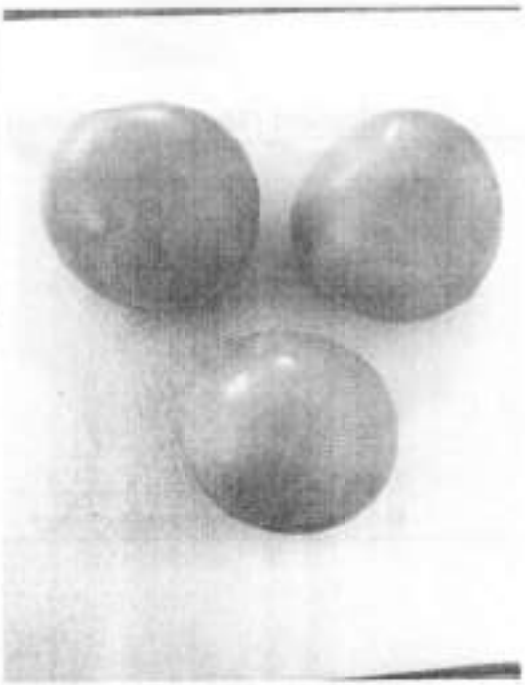
Kharua brinjal (Solanum *sp.)*,



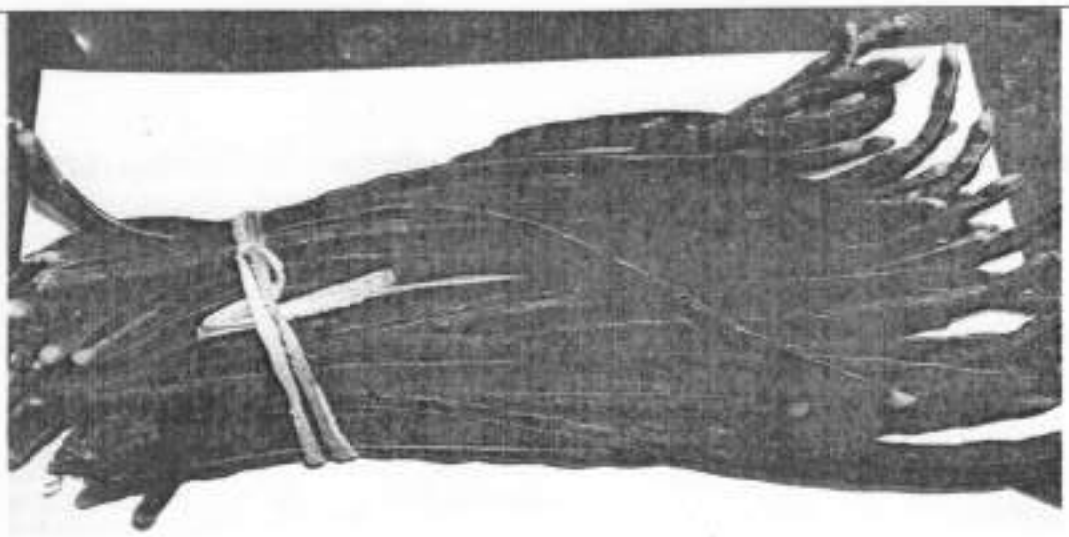
Pumpkin *(cucurbita moschata)*



Bottlegourd (*Lagenaria siceraria*)



Tomato (*Solanum lycopersicum)*



Black eyed pea (*Vigna unguiculata* subsp. *Unguiculata*)

Roselle (*Hibiscus acetosella*)

ज्ञान-विज्ञान विमुक्तये

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG

NEW DELHI – 110 002

STATEMENT OF EXPENDITURE IN RESPECT OF MAJOR/MINOR RESEARCH PROJECT

a. Name of Principal Investigator: **Prof. C.L. Mahanta**

b. Deptt. of University/College: **Deptt. Food Engineering & Technology,Tezpur University**

c. UGC approval No. and Date: **37-1/2009 (SR), 12-01-2010**

d. Title of the Research Project: **Antioxidant capacity of fresh & variously processed fruits & vegetable of Assam**

e. Effective date of starting the project: **17-06-2010**

f. i. Period of Expenditure: From **01-04-2010** to **31-03-2011**

Sl. No.	Items	Amount Approved (Rs.)	Amount Received as first Installment (Rs.)	Expenditure Incurred in First year (Rs.)
1	Books & Journals	Nil	Nil	Nil
2	Equipment	3,00,000.00	3,00,000.00	1,96,969.00
3	Contingency	6,000.00	3,000.00	3000.00
4	Field Work/Travel (Give details in the proforma at Annexure- VII).	40,000.00	20,000.00	19,099.00
5	Hiring Services	Nil	Nil	Nil
6	Chemicals & Glassware	4,00,000.00	2,00,000.00	1,82,390.00
7	Overhead	69,400.00	69,400.00	66,507
8	Project fellowship @8,000/- p.m (Pre-revised rate)	4,55,467.00	1,44,000.00	75,733.00
	Total expenditure (Rs.)	12,70,867.00	7,36,400.00	5,43,698.00
	Unspent Balance (Rs.)	----	----	1,92,702.00

ii. Period of Expenditure: From **01-04-2011** to **31-03-2012**

Sl. No.	Items	Amount Approved (Rs.)	Amount Received as first Installment (Rs.)	Expenditure Incurred (Rs.)
1	Books & Journals	Nil	Nil	Nil
2	Equipment	3,00,000.00	3,00,000.00	1,10802.00
3	Contingency	6,000.00	3,000.00	Nil
4	Field Work/Travel (Give details in the proforma at Annexure- VII).	40,000.00	20,000.00	Nil
5	Hiring Services	Nil	Nil	Nil
6	Chemicals & Glassware	4,00,000.00	2,00,000.00	Nil
7	Overhead	69,400.00	69,400.00	Nil
8	Project fellowship @8,000/- p.m (Pre-revised rate)	4,55,467.00	1,44,000.00	72,000.00
	Total expenditure (Rs.)	12,70,867.00	7,36,400.00	1,82,802.00
	Unspent Balance (Rs.)	----	----	9,900.00

iii. Period of Expenditure: From **01-04-2012** to **31-03-2013**

Sl. No.	Items	Amount Approved (Rs.)	Amount Received as second Installment (Rs.)	Expenditure Incurred (Rs.)
1	Books & Journals	Nil	Nil	Nil
2	Equipment	3,00,000.00	Nil	Nil
3	Contingency	6,000.00	3,000.00	3000.00
4	Field Work/Travel (Give details in the proforma at Annexure- VII).	40,000.00	20,000.00	20413.00
5	Hiring Services	Nil	Nil	Nil
6	Chemicals & Glassware	4,00,000.00	2,00,000.00	2,03,109.00
7	Overhead	69,400.00	Nil	Nil
8	Project fellowship @14,000/- p.m (Revised rate)	4,55,467.00	2,21,320.00	2,06,000.00
	Total expenditure (Rs.)	12,70,867.00	4,44,320.00	4,32,522.00
	Unspent Balance (Rs.)	----	----	11,798.00

i. Staff

Date of Appointment: 17-06-2010

1. It is certified that the appointment(s) have been made in accordance with the terms and conditions laid down by the Commission.
2. It as a result of checks or audit objective, some irregularly is noticed, later date, action will be taken to refund, adjust or regularize the objected amounts.
3. Payment @ revised rates shall be made with arrears on the availability of additional funds.

4. It is certified that the grant of **Rs. 7, 36,400.00 (Rupees seven lakh thirty six thousand four hundred only)** received from the **first installment** and grant of **Rs. 4, 44,320.00 (Rupees four lakh fouty four thousand three hundred twenty only)** as **second installment** from the University Grants Commission under the scheme of support for Major Research Project entitled **Antioxidant capacity of fresh & variously processed fruits and vegetables of Assam** vide **UGC letter No. F. 37-01/2009 (SR) dated 12-01-2010.** Total of **Rs. 5, 43,698.00** between the period from **01-04-2010 to 31-03-2011** and **Rs. 1, 82,802.00** in the period from **01-04-2011 to 31-03-2012** from the **first installment** and **Rs. 4, 32,522.00** from the **second installment** between the period from **01-04-2012 to 31-03-2013** has been utilized for the purpose for which it was sanctioned and in accordance with the terms and conditions laid down by the University Grants Commission.

Chiranjib Kalita
Inspire

SIGNATURE OF PRINCIPAL INVESTIGATOR

20 Oct 13

REGISTRAR

iv. **Consolidated expenditure statement:**

Sl. No	Items	Amount Approved (Rs.)	Amount Received as 1st Installment (Rs.)	Expenditure 1st year (01-04-2010 to 31-03-2011)	Expenditure 2nd year (01-04-2011 to 31-03-2012)	Amount Received as 2nd Installment (Rs.)	Expenditure 3rd year (01-04-2012 to 31-03-2013)
1	Books & Journals	Nil	Nil	Nil	Nil	Nil	Nil
2	Equipment	3,00,000.00	3,00,000.00	1,96,969.00	1,10802.00	Nil	Nil
3	Contingency	6,000.00	3,000.00	3000.00	Nil	3,000.00	3000.00
4	Field Work/ Travel (Give details in the proforma at Annexure- VII).	40,000.00	20,000.00	19,099.00	Nil	20,000.00	20413.00
5	Hiring Services	Nil	Nil	Nil	Nil	Nil	Nil
6	Chemicals & Glassware	4,00,000.00	2,00,000.00	1,82,390.00	Nil	2,00,000.00	2,03,109.00
7	Overhead	69,400.00	69,400.00	66,507	Nil	Nil	Nil
8	Project fellowship @14,000/-p.m for 1st & 2nd year and @ 16,000/-pm for 3rd year (Revised rate)	4,55,467.00	1,44,000.00	75,733.00	72,000.00	2,21,320.00	2,06,000.00
	Total Spent (Rs.)	12,70,867.00	7,36,400.00	5,43,698.00	1,82,802.00	4,44,320.00	4,32,522.00
	Unspent Balance (Rs.)	-	-	1,92,702.00	9,900.00	-	11,798.00

FOOTNOTE:

1. Fund Released in 1st installment- Rs. 7, 36,400.00
2. Expenditure (1st year, from 01-04-2010 to 31-03-2011) - Rs. 5, 43,698.00
3. Expenditure (2nd year, from 01-04-2011 to 31-03-2012) - Rs. 1, 82,802.00
4. Unspent balance amount - Rs. 9,900.00
5. Fund Released in 2nd installment - Rs. 4, 44,320.00
6. Expenditure (3rd year, from 01-04-2012 to 31-03-2013) - Rs. 4, 32,522.00
7. Unspent balance amount Rs. 11,798.00