CHAPTER 5

SUMMARY AND CONCLUSIONS

Selected fruits (kinnow, jambolan, pomegranate, mango, sapodilla, banana and grapes) and vegetables (black carrot, beetroot, orange carrot, brinjal, bitter gourd, spinach and mentha) were evaluated for color parameters, chemical composition (minerals, dietary fiber and proximate), antioxidant activities (using ABTS and DPPH assays) and profiles of polyphenolic compounds (using RP-HPLC). In addition, antioxidant as well as antimicrobial activities of JNFP against some reference pathogenic strains were examined and then compared with some standard polyphenolic compounds. Apart from this, few selected fruits and vegetables were examined for their possible utilization in extruded products (beetroot) and gluten-free muffins (jambolan and black carrot). Summary of the study is presented in the following subsections:

5.1. COMPOSITION, BIOACTIVE COMPOUNDS AND ANTIOXIDANT ACTIVITY OF SELECTED FRUITS (PEELS AND PULPS) AND VEGETABLES

Deseeded fruits [separated into peel (inedible) and pulp (edible) portions, except for jambolan and grapes owing to their edible skins] and vegetables were homogenized, freeze dried and afterwards powdered. The $L^*$ value ranged from 36.2 to 54.7 for different fruits and 21.1 to 47.6 for different vegetables, while the $a^*$ values ranged from -2.2 to 14.0 for different fruits and from -10.0 to 22.4 for different vegetables. It was observed that all fruits and vegetables showed positive $b^*$ values, which ranged from 0.3 to 42.0 for different fruits and 0.3 to 31.2 for different vegetables. The ash content ranged from 2.6 to 5.2% and 3.2 to 4.3% for different fruits and vegetables, respectively. On the other hand, the protein content ranged from 1.4 to 2.4% for different fruits and 1.1 to 3.3% for different vegetables. The amounts of macroelements Na, K, Ca and Mg ranged from 31 to 138, 135 to 444, 52 to 320 and 43 to 147 mg/100 g DW, respectively for fruits, while from 15 to 182, 357 to 819, 25 to 180 and 71 to 182 mg/100 g DW, respectively for vegetables. The amounts of microelements Fe, Cu, Zn and Mn ranged
from 0.21 to 4.02, 0.06 to 0.76, 0.13 to 1.51 and 0.03 to 0.69 mg/100 g DW, respectively for fruits, while from 4.16 to 9.49, 0.11 to 0.70, 0.55 to 2.75 and 0.39 to 4.96 mg/100 g DW, respectively for vegetables. Fruit peels had higher concentrations of different minerals, while different vegetables had higher content of various minerals as compared to fruits.

The TPC ranged from 354.9 to 1639.7 mg GAE/100 g DW for fruits, while it ranged from 179.3 to 1028.6 mg GAE/100 g DW for vegetables. DPPH antioxidant activity ranged from 2.6 to 5.5 mM TE/g DW for different fruits, while it ranged from 2.1 to 4.7 mM TE/g DW for different vegetables. On the other hand, ABTS antioxidant activity ranged between 3.0 and 6.3 mM TE/g DW for different fruits, while it ranged between 2.0 and 5.0 mM TE/g DW for different vegetables. Notably, the fruit peels had higher TPC, DPPH and ABTS antioxidant activity than their respective pulps.

HPLC analysis showed the presence of a number of polyphenolic compounds in different fruits and vegetables (caffeic acid, protocatechuic acid, gallic acid, resveratrol, catechin, sinapic acid, ferulic acid, kaempferol and quercetin). Gallic acid (ranged from 6.6 to 52.3 mg/100 g DW) was present in all fruits (except kinnow) and in most vegetables (except orange carrot, spinach and brinjal). Catechin (ranged from 5.3 to 76.5 mg/100 g DW) was present in most fruits, except kinnow and jambolan. Pomegranate peel and pulp had the highest amount of catechin, which was followed by banana and then sapodilla. Caffeic acid (ranged between 4.7 to 67.6 mg/100 g DW) was observed in all fruits (except sapodilla), while it was not present in pomegranate and mango pulps. Sinapic acid was present in jambolan, pomegranate, grapes and kinnon, while resveratrol was observed in banana, pomegranate, mentha, spinach and grapes only. In addition, caffeic acid was present in all vegetables (with the exception of spinach). Quercetin (ranged between 5.4 and 49.1 mg/100 g DW) was present in most fruits except kinnow, while it was observed in black carrot, beetroot, and spinach only in case of vegetables. All fruits and vegetables had higher IDF content than SDF content. TDF content ranged between 7.0 and 18.8 g/100 g DW for fruits, while it ranged from 13.6 to 19.3 g/100 g DW for vegetables. Further, it was observed that fruit peels had higher TDF content than their respective pulps (with the highest for sapodilla). Vegetables contained higher amounts of IDF but lower of SDF than different fruits. The study provided useful
information that is essential for the understanding of nutraceutical potential as well as future application of different fruits and vegetables in the food industry. Fruits and vegetables were not only good sources of bioactive constituents but also essential minerals, while fruit peels were superior to pulps in this regard. Moreover, the antioxidant activities of fruits and vegetables were dependant on the polyphenolic content.

5.2. IN VITRO ANTIOXIDANT AND ANTIMICROBIAL PROPERTIES OF JAMBOLAN FRUIT POLYPHENOLS

TPC for JNFP was 1174 mg GAE/100 g DW. DPPH antioxidant activity of JNFP was 6.7 mM TE/g DW. Among the standard polyphenolic compounds, gallic acid showed the highest scavenging, which was followed by quercetin, delphinidin chloride, sinapic acid and lastly caffeic acid. On the other hand, ABTS antioxidant activity was 8.2 mM TE/g DW for JNFP. Quercetin showed the highest ABTS antioxidant activity, which was followed by delphinidin chloride, gallic acid, sinapic acid and lastly caffeic acid.

JNFP exhibited a broad spectrum antimicrobial activity not only against Gram-positive (\textit{S. aureus} and MRSA) bacteria, but also against Gram- negative ones (\textit{E. coli} and \textit{K. pneumoniae}). Additionally, a positive activity was also shown against \textit{C. albicans}. \textit{S.aureus} was the most sensitive organisms to JNFP having an inhibition zone of 23.0 mm, whereas \textit{C. albicans} was the least sensitive with an inhibition zone of 14.3 mm. Notably, JNFP was able to inhibit the growth of MRSA with an inhibition zone of 16.0 mm. Minimum inhibitory concentration values of JNFP ranged from 0.5 to 2.5 mg/mL for the tested reference microorganisms. Other standards also (especially gallic acid) at lower concentrations were able to inhibit the growth of most tested reference microorganisms, but caffeic acid was not effective against MRSA. The results suggested that JFNP can be a useful natural preservative and work as a natural therapy for treating various infections that are caused by pathogenic microorganisms. In addition, JFNP may also be useful in a synergistic approach along with conventional antibiotics.
5.3. UTILIZATION OF POLYPHENOLIC COMPOUNDS AND DIETARY FIBER FROM VARIOUS SOURCES IN DIFFERENT FOOD PRODUCTS

5.3.1. Utilization of beetroot in corn based extrudates

The influence of BTP incorporation (0, 5, 10 and 15%) at various extrusion temperatures (125, 150 and 175 °C) on the physicochemical, antioxidant activity and sensory properties of corn grit extrudates was studied. Pasting temperatures of corn grit as well as corn grit + BTP blends ranged between 77.5 and 78.3 °C. The highest pasting temperature was for corn grit which had the highest level (15%) of BTP. Peak viscosity decreased by increasing the BTP addition (from 2591 to 2058 cP). Similarly, breakdown viscosity decreased with the increase in beetroot addition (from 853 cP to 518 cP). A decrease in the SME from 111 to 63 kWh/ kg was observed with increase in BTP incorporation and extrusion temperature. Extrudates having BTP had a lower \( L^* \) value as compared to those from corn grit only. The \( a^* \) value increased progressively with the BTP addition (from 2.3 to 11.6), while \( b^* \) value decreased. A significant reduction in the expansion ratio of extrudates was observed BTP incorporation, but extrusion temperature did not show any significant effect. A reduction in the WAI was observed with the incorporation of BTP, while WAI increased with the increase in extrusion temperature. Additionally, a gradual decrease in WSI was observed with BTP incorporation. Hardness of the extrudates increased with an increase in BTP incorporation, while it decreased with increasing extrusion temperature. The overall acceptability, colour, mouthfeel and appearance scores of the extrudates ranged from 5.1 to 7.50, 6.4 to 7.8, 4.6 to 7.4 and 4.2 to 7.6, respectively. The extrudates having 10% BTP showed the highest scores for overall acceptability, appearance and mouthfeel, while the highest scores for color were observed for 15% BTP incorporation.

X-ray diffraction analysis of the extrudates showed that the extrudates were mainly amorphous, exhibiting fewer peaks (of low intensities) at \( \sim 14, 17 \) and \( 18° \) 2\( \theta \); and the intensity of these peaks reduced further slightly when the extrusion temperature was increased. The TPC ranged from 73.2 to 157.2 mg GAE/100 g DW for the extrudates having different levels of incorporated BTP. TPC increased significantly with BTP incorporation but decreased significantly with the increase in extrusion temperature. DPPH antioxidant activities ranged from 1.1 to 2.1 mM TE/g DW for different
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extrudates. DPPH inhibition increased with the BTP incorporation. Similarly, ABTS inhibition for extrudates increased with BTP incorporation and it ranged from 1.9 to 2.7 mM TE/g DW. TDF content ranged from 2.7 to 4.2 g/100 g DW for different extrudates and increased with BTP incorporation. The results showed that BTP incorporated corn grit extrudates had the potential to enhance the nutrient density of the traditionally prepared extrudates.

5.3.2. Utilization of jambolan in gluten-free muffins

Gluten-free eggless rice muffins incorporated with varying levels (0, 10, 20 and 30 g for 100 g flour) of JNP with/without 0.5 g XNG were analyzed for physicochemical, textural and sensory properties. In addition, their batters were evaluated for fundamental rheology. The addition of JNP and XNG increased the batter viscoelasticity, where an increase in $G'$ (from 63 to 2734 Pa) and $G''$ (from 22.8 to 608 Pa) was observed, while tan $\delta$ decreased from 0.37 to 0.21. The $L^*$ value for both muffin crusts and crumbs decreased with JNP addition, while it increased in crumbs only with XNG addition. On the other hand, the $a^*$ value of muffin crusts as well as crumbs decreased and became more negative by increasing JNP levels. Muffins made from rice flour alone had the highest height (35.6 mm), while the it decreased (to a value of 31.4 mm) with an increase in the level of JNP addition. Moreover, the specific volume of muffins decreased slightly with JNP addition (lowest for 30 g JNP without XNG addition), with the highest value being for 0 g JNP with XNG addition. Firmness of the muffins firstly increased to its highest value at an incorporation level of 10 g JNP, and afterwards decreased with higher levels. XNG addition did not affect the springiness, but it increased the cohesiveness, resilience and firmness of the muffins. The $a_w$ decreased with increasing JNP incorporation levels and XNG addition (lowest for the muffins made with 30 g JNP incorporation). The evaluated TPC for muffins ranged from 42.12 to 63.79 mg GAE/100 g DW. JNP incorporation at increasing levels increased the TPC of the muffins, while no significant effect was observed with XNG addition. In addition, the DPPH antioxidant activity increased significantly with an increase in the level of JNP (highest for muffins having 30 g JNP incorporation). Muffins prepared with 30 g JNP had the highest ABTS antioxidant
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activity (1.7 mM TE/g DW). The overall acceptability, color, texture, taste and appearance scores of muffins with JNP incorporated at various levels ranged from 7.0 to 8.4, 7.6 to 8.6, 6.6 to 8.2, 7.4 to 8.6 and 6.4 to 8.2, respectively. Muffins having 30 g JNP with XNG addition showed the highest scores for all the determined sensory characteristics. The results indicated that JNP can be successfully added to gluten-free muffin recipes and improve their consumer acceptability. These muffins would not only scavenge free radicals but also have a slightly longer shelf life than traditional ones.

5.3.3. Utilization of black carrot in gluten-free muffins

BDF was incorporated at three levels (3, 6 and 9%) in rice flour with/without XNG to study its effect on muffin-making properties. Water absorption capacity was 9.89 g/g for BDF, while it was 1.53 g/g for rice flour. The pasting temperature varied from 79.7 to 88.9 °C. The lowest peak viscosity was observed for rice flour (1840 cP), while it increased with increasing level of BDF and XNG addition. Final viscosity increased with the increase in the level of BDF incorporation, with the highest for 9% BDF plus XNG blends (3770 cP). $G'$ and $G''$ values were the highest for batters having 9% BDF with added XNG (1691.7 and 576.2 Pa, respectively), while the lowest was for batters made from rice flour alone (108.8 and 32.8 Pa, respectively). Moreover, XNG also increased the $G'$ and $G''$ of the batters. The $a^*$ value of crumbs and crusts decreased up to 6% BDF incorporation, followed by an increase at 9% level. The specific volume of muffins decreased with BDF incorporation (being highest for 0% BDF with XNG) and was the lowest for 9% BDF without XNG addition. However, XNG did not show any significant changes in the specific volume of muffins up to a 6% BDF level, while it increased at 9% BDF level. The height of muffins decreased gradually with the increasing level of BDF, while it increased with XNG addition. Both BDF incorporation and XNG addition significantly decreased $a_w$ of muffins. Firmness increased with the decrease in the level of BDF (from 1.3 N to 2.4 N), while it increased with XNG addition. On the other hand, cohesiveness had the minimum value in muffins containing 9% BDF, while it increased with the decrease in the level of BDF. TDF of muffins increased significantly from 0.83
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to 1.84 g/100 g DW with BDF incorporation. Overall acceptability, taste, texture, appearance and color scores of muffins containing varying levels of BDF ranged from 6.6 to 7.4, 7.2 to 7.7, 6.4 to 7.2, 6.4 to 7.4 and 6.2 to 7.2, respectively. These results indicated that muffins having the highest sensory scores could be prepared using 6% BDF with 0.5 g XNG addition. BDF and XNG are potential ingredients for new functional foods.