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Overview of *Cucurbita* spp. (pumpkin) and development of value-added products emphasizing its nutritional and chemical composition

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Abstract

Pumpkin (*Cucurbita* spp.) is a commonly grown vegetable across the world however, due to its underutilization as a food source a significant imbalance between pumpkin production and consumption has been identified. Many researchers have reported morphological diversity and differences in the nutritional and chemical composition among the pumpkin species which resulted in a selective distribution of *Cucurbita* species in different parts of the world. As evidenced from literature, pumpkin has been identified as a remarkable source of nutrients and reported with high protein, carbohydrate, vitamins, and especially with high amounts of antioxidants. Despite their nutritional value, post-harvest loss associated with pumpkins is significantly high which highlights the importance of utilization of pumpkins through value addition. The value addition of pumpkin has drawn a huge research interest over the past years which has emphasized the nutritional and chemical composition of pumpkin, especially in the edible (flesh, seeds) and non-edible (peel and pulp) fruits parts and pumpkin flowers in several value additions. This review furnishes an overview of *Cucurbita* spp. production and the post-harvest loss associated with pumpkin along with the updated information about the reported value additions based on existing literature.

Keywords: *Cucurbita* spp.; Underutilized crop; Value addition; Morphological variation; Nutrient composition

1. Introduction

Pumpkin (2n = 2x = 40) is a seasonal vegetable crop that belongs to the Family Cucurbitaceae and genus *Cucurbita* [1]. This plant family is considered one of the largest families in the plant Kingdom with a large number of edible plants with 8 tribes, 118 genera, and 825 species [2,3].

Taxonomic classification of *Cucurbita* spp.;

- Kingdom – Plantae
- Division – Tracheophyta
- Class – Magnoliopsida
- Order – Cucurbitales
- Family – Cucurbitaceae
- Genus – *Cucurbita*
- Species – *C. maxima*, *C. pepo*, *C. moschata*, *C. ficifolia*, *C. palmata*, *C. argyrosperma*

In different countries pumpkins are recognized in different names. In India, they are known as Sitaphal, Katiphal and Kaddu while in Bangladesh pumpkins are known as Mistikumara [4]. Common English names like Squashes, Gourds are also used to name *Cucurbita* fruits [5]. Pumpkins are considered to be native to Central and South America [6]. According

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to Lanka [7], there are five main species that are being cultivated around the world as pumpkins including *C. maxima*, *C. moschata*, *C. pepo*, *C. mixta*, *and C. ficifolia*. Among these species, *C. maxima* is considered as the earliest species domesticated in South America and then associated with human consumption for more than 12000 years [8] . Even though the domestication and the origin have been initiated along with the South and Central American regions they are now distributed extensively and grown around the tropical and sub-tropical and temperate countries including Asia, Africa, Europe, and the Oceanic continents and producing more than 20 million tons annually [9,10]. According to the study conducted by [11], pumpkin (*Cucurbita* spp.) is considered the most abundantly consuming vegetable in Bangladesh and is cultivated worldwide for multiple purposes as agricultural, economic and cultural. Pumpkin is identified as a temperature sensitive crop and for a maximum production the temperature should be in 20-35 ^{0}C range and should be free from freezing periods and high humid conditions [12]. According to Pushpakumari *et al.* [13], in Sri Lanka, pumpkin cultivation is done in both *Yala* and *Maha* seasons but prominent in *Maha* season than the *Yala* season due to the favourable climatic conditions during that season. And the cultivation is covering the dry and intermediate zones in the island with around 500 m elevation. Pumpkins are generally harvested at their fullest maturity stage and the maturity level identification is basically depending on several morphological characteristics of the crop and duration of planting, flowering etc. And also for most of the pumpkin varieties, harvesting is possible after 3 months from sowing and 1-2 months after flowering. Pumpkin harvesting is a manual process which is performed by clipping off the fruit from the vine, as around 2-3 cm long stalk part is remaining with the fruit [14]. Improper and non-scientific post-harvest handling practices during the market chain, lack of resources and lack of awareness have created a considerable quantitative and qualitative loss of foods. This prevents reaching of economic benefits to the ground level farmers and good quality products to the consumers at the end. For vegetables, the estimated annual post-harvest loss is between 20-40 % where for fruits, it is between 30-40 % [15].

Many research studies have been highlighted the potential importance of pumpkin fruits, seeds, pulp and flowers in nutritional, medicinal and pharmacological aspects due to the nutritional and phytochemical composition of pumpkin [16]. The nutrient and chemical composition of pumpkin has drawn a remarkable research interest in development of several value-added products from pumpkin.

This review highlights the worldwide distribution and production of *Cucurbita* spp., morphological variation among different *Cucurbita* species, post-harvest loss associated with pumpkin, nutritional and chemical composition of *Cucurbita* fruits, and potential benefits of pumpkin consumption addressing nutritional and nutraceutical aspects. In addition to that, this review provides insights to the development of pumpkin based value added products highlighting the currently reported pumpkin based value additions.

2. Pumpkin production

According to [17], *Cucurbita* spp. is considered a one of the 10 leading vegetables worldwide. Among the domesticated pumpkin species, three *Cucurbita* species including *C. maxima, C. moschata and C. pepo* are economically important and cultivated in large scale worldwide [18]. Pumpkin is considered one of the most overlooked but yet underutilized crops with significant horticultural benefits that makes the expansion of the production annually worldwide [19]. And the production of pumpkin has become hindered by the lack of availability of genetically improved seeds compared to three main crops Rice, Maize, Wheat that account for more than half of global energy supply [20].

2.1. Optimum growth conditions

Optimum temperature for pumpkin cultivation is reported in between 25-30 ^{0}C [12]. However, temperature tolerant accessions have also been developed in most of the temperate and cold region countries like Russia with 2064 accessions, Germany with 857 accessions, Spain with 925 and Hungary with 732 accessions [19]. Soil temperature should be above 16 ^{0}C at the stage of germination and well-drained, fertile soil with pH 6-6.5 up to 2-3 feet from the top is favoured. Irrigation needs to be optimum at the level of 6-8 mega litres per hectare during the full crop cycle. Irrigation plays an important role during the flowering and the fruiting stages where the osmotic stress, building up within the plant causes for the immature fruit falling off from the plant [12].

2.2. Global production

Pumpkins are being cultivated around the world over 3 million hectares that yields over 27 million tons. The world's leading pumpkin producer is China with 58 % production per year [19]. India is having 45,000 hectares of pumpkin cultivation that produces around 5 million metric tons per year, with an average weight of 8-10 kg in fruits. And also in India, the main growing season is summer and rainy periods for most varieties but the Southern and Western parts of India are cultivating the winter varieties during the winter season [21]. According to the study conducted by Wittstruck [22] in Germany, the pumpkin production has been characteristically increased over 5000 hectares at the year of 2018

compared to the last two decades. In Sri Lanka, during the *Maha* season in 2010, the cultivation extent was 3742 hectares with 42,715 metric ton production and in *Yala* season, it was 2737 hectares with 24,4637 metric tons [13]. Monaragala, Anuradhapura, Rathnapura, Hambanthota, Mahaweli system H, Mathale has been identified as the areas where the pumpkin cultivation is highest in Sri Lanka [13].

Compared to the other parts of the world, East African regional countries are having a lesser production scheme of pumpkin due to the over reliance on some staple crops like cassava, maize, sorghum, millet while neglecting the conservation of plant genetic materials of nutritious but under-utilized crops like pumpkin which has driven a lesser interest in the small-scale farmers towards the pumpkin production [23].

In some countries the production is species oriented. According to Zhou *et al*. [24] in China, they are mainly cultivating the *C. moschata and C. maxima* and paying less interest towards the *C. pepo*, which has a less consuming rate compared to the other cucurbits. But in Egypt, the most popular species is the *C. pepo* where the others are cultivated in lesser amounts [25]. In Sri Lanka, there are different pumpkin varieties that are being cultivating, which belong to *C. maxima* and *C. moschata*. Arjuna, ANK Ruhunu, Meemini, Rajah, Katana, Bingha, Pathma, Butternut, Leela, Lanka, MK Spanchy, Samson, Monica, Arela, Peta, Goldma. Cheonlima, Shiba are some of those varieties [6,7].

3. Morphological characteristics

Pumpkin is a fruit-bearing, creeping plant where the stem can be elongated up to more than 10 m in length when ideal field conditions are met [26]. The plant consists of both vegetative and reproductive structures (Figure 1). Vegetative structures include the leaves, roots, stem, and tendrils. Reproductive structures include fruits and flowers.

3.1. Vegetative structures

Leaves – Ovate-cordate to suborbicular-cordate leaves with 5-25 cm length petioles can be observed in pumpkin with or without white spots on the leaf surface. And also characteristically in the leaves 3 to 5 lobules can be identified where the middle one is larger than the lateral lobules which are rounded, apiculate or obtuse in shape [26].

Stem – Stems are often rough and angular producing roots at the knots. In most cases, it is a creeping stem but in trunk varieties there can be observed semi-erected stems with short internodes also. Stems can be elongated into 10-30 m in length in some varieties [27].

Roots – Rooting is happened at the nodes and it increases its potential through secondary root growth to develop a strong tap root system grow as deep as 2-3 feet. Roots do not contain swollen reserves which makes *Cucurbita* spp. a short-lived perennial [19].

Tendrils – Thin whip-like tender structures that are attached to the stem along the vine, important in plant creeping and attachment. Appeared in green color and capable of photosynthesizing. And these tendrils are considered as leaf modifications without leaf blades.

3.2. Reproductive structures

Family Cucurbitaceae shows a broad diversity in the reproduction and as the most prevalent sexual reproduction method, monoecious reproduction system has been identified [19]. As stated in Nashath *et al*. [28], pumpkins are a monoecious crop where their female and male sexual components of bloom separately produced in the same plant.

Flowers – Consist of five petals which are different in size, shape and color in different pumpkin varieties [28]. There are characteristic morphological differences between male and female flowers in the same plant; in their size, shape and floral structures which is shown in Figure 2. According to the study conducted by Yadav *et al*. [26], the male flowers are pedicellated and wide and long, comprising a 5-10 mm size campanulate calyx, tubular campanulate corolla, linear sepals and three distinguishable stamens. And also the study has shown that, the female flowers of pumpkin have a larger corolla than the male flowers, occasionally foliaceous sepals, shorter peduncle and thickened style with three lobate stigmas. The production ratio of male flowers and female flowers within a plant is considered to be 4:1 to 17:1 [3].

Fruits – The fruit size, shape and color among the genus and species are widely diversified (Figure 3). The Cucurbitaceous fruits can be globose to ovoid with approximately three color patterns as dark to light green with or without white longitudinal lines, green color with white spots and orange, white and cream colored spots [26].

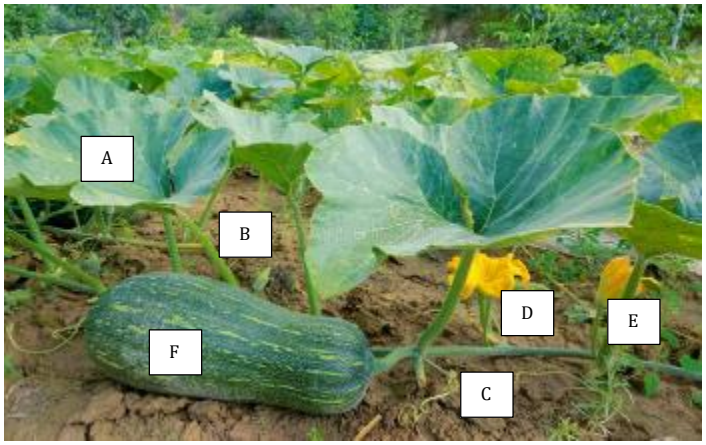

Figure 1 Morphological parts of a *Cucurbita* spp. plant; A-leaves, B-stem, C-tendrils, D-female flower, E-male flower, and F-fruit. Source: https://www.dreamstime.com/pumpkin-plant-bearing-fruit-field-image194091322#

Figure 2 Morphological difference between Female and male flowers of *Cucurbita* spp.; A- female flower and B- male flower. Source: Adapted and modified from Ghosh & Rana [29].

Figure 3 Morphological variation in fruit shape of pumpkins; A- globular, B- flattened, C- ovate, D- elongate, E- acorn, F- pyriform and G- elliptical. Source: Adapted from Kiramana & Khasungu Isutsa [3]

3.3. Morphological difference among *Cucurbita* spp.

Phenotypic variation is higher among *Cucurbita* species and they are characteristically varying in their shape, size, color, flesh characteristics, seed number and seed characteristics [3]. Morphological variation observed in different cucurbits is displayed in Figure 4. Consideration of these characteristics in different pumpkin varieties is the easiest way of distinction and identification of different varieties and species of pumpkin [3]. A study conducted by Ahamed *et al*. [4], have stated that there has a significant difference among 20 different genotypes of *C. moschata* in their morphological characteristics including vine length, number of branches per plant, leaf length, leaf diameter, fruit color, fruit shape and their flesh color.

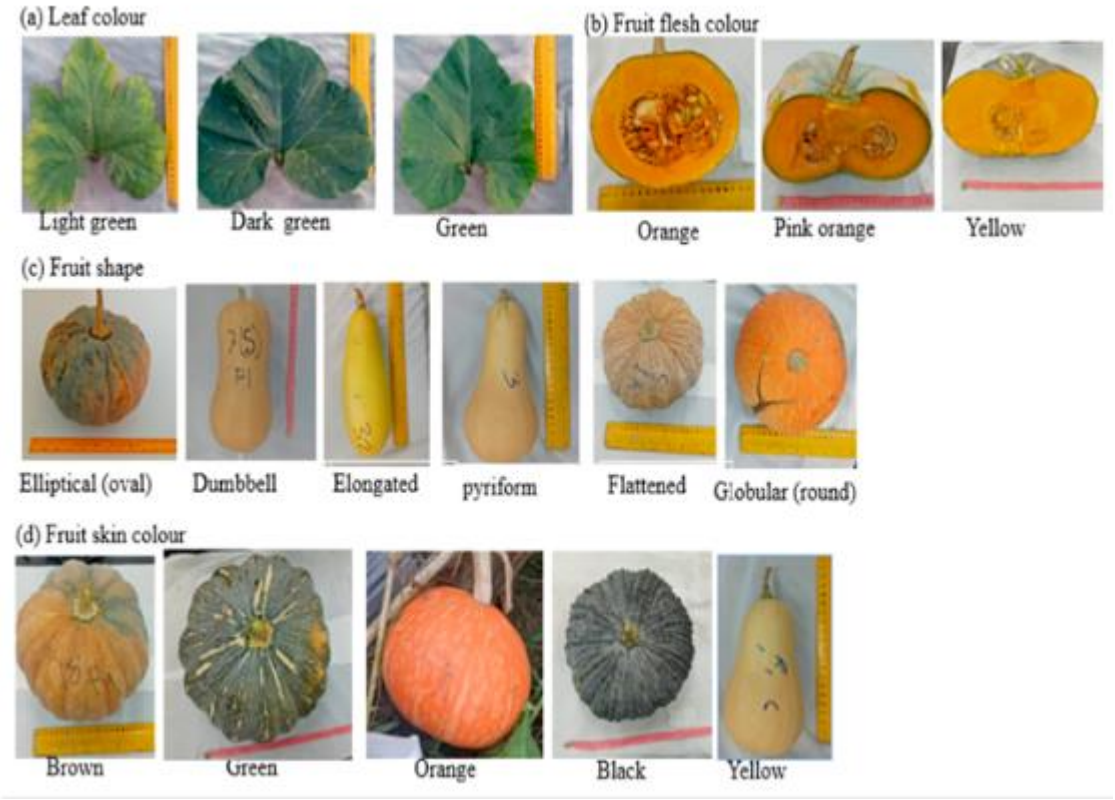

Figure 4 Morphological difference between *Cucurbita* spp.; Morphological variation observed in (a) their leaf color, (b) fruit flesh color, (c) fruit shape and (d) fruit skin color. Source: Adapted from Hosen *et al*. [19]

C. moschata – This has a succulent hairy stem which usually grow up to 3 m at the maturity. Separate female and male flowers can be identified and the leaves are slightly lobed with distinct white spots in their veins. Fruits are considerably large varying from globose to flatten in their shape. The root system is characteristically fibrous. And blooming occurs between 35-60 days after emergence where the fruits get matured after 4-6 weeks after flowering [12]. *C. maxima* – Stems are rigid, angular and spiky. Both female and male flowers can be identified in the same plant. The fruit is larger and considered to be the largest fruit producer among the family. The fruits can be weighted between 4-35 kg and fruits are characteristically flattened resembling the typical pumpkin shape [3, 30]. *C. pepo* – The stems are fleshy, stout and develop large number of tendrils. The leaves are simple and slightly lobed and can be 20-30 cm in width. Both female and male flowers can be identified in the same plant. The species is characterized by its robust and pentagonal fruiting pedicel. Fruits are relatively smaller relative to the fruits produced by other species and shows a broad diversity in fruit colour and size among different varieties [31].

4. Harvesting and post-harvest practices

After harvesting at the proper harvestable maturity stage, under optimum temperature and humidity conditions most of the pumpkins can be stored for up to 8 months [14]. According to DOA in Sri Lanka [32], ANK Ruhunu, Pathma and local varieties can be stored up to 6-8 months where the Butternut variety can be stored only for one month under ambient conditions. The storage time of fruits depends on the harvesting process and the post-harvest handling

practices. Post-harvest practices are identified as the subsequent processes which are followed immediately after the harvesting and up to the stage where the consumer receives the final product [33].

4.1. Maturity level identification at harvesting

Over matured and immature fruits are lack of storage life after harvesting compared to the fruits which have harvested in the correct maturity stage [34]. According to Cantwell [35], maturity defines as the developmental stage of a particular commodity which satisfies its minimum acceptable quality required by the consumer. And the maturity index is a measurement that is used to identify whether a commodity has been reached for its desired maturity stage or not. Chronological features, physical features and chemical changes are considered as maturity indices and implementation of these indices are entirely depending on the characteristics of the targeting commodity.

Carren [14] stated that, the most effective maturity indices regard to the pumpkins are the changes in the physical appearance in both fruits and the plant. As it states, at their maturity stage pumpkin fruits loose its shiny appearance on the surface and become waxier and less shiny. And also the surface colour becomes brighter which would be characteristic to each variety. In addition to these changes, the rind tissues of the fruit become noticeably harder to get punctured by a thumbnail at the level of maturity. Stem changes from a uniform, green coloured and slightly succulent texture into a brownish and dry stem at the places where the fruits have attached to the vine. And also the death of tendrils, nearest to the fruits indicates the harvestable maturity level of pumpkins.

4.2. Post-harvest loss and management

According to study conducted by Mohammed [36] in Trinidad and Tobago, the calculated average post-harvest loss percentage of pumpkins in wet season is 28.1 and dry season, it is 18.6. And also this values become even higher during the exportation compared to the direct selling within the country. This study has outlined the improper post-harvest practices followed during the market chain, which cause this loss of pumpkins. According to that, fruits lose their marketable quality due to the physical injuries caused during harvesting, transporting, curing, sorting, packaging and storing. Quality loss also occur in pumpkins due to the post-harvest decay caused by the micro-organisms. Fungal species like *Fusarium* spp., *Rhizopus* spp., *Phytopthora* spp., *Pythium* spp., *Penicillium* spp. and bacterial species like *Erwinia carotovora* and *E. chrysanthemi* have been identified as some of the common organisms that causes the deterioration of harvested fruits [34]. According to Naureen *et al*. [37], they have recognized *Fusarium solani*, *Cladosporium* sp., *Geotrichum candidum* and *Drechslera australinsis* as the key fungal species that cause post-harvest decay in pumpkins in Karachi, Pakistan.

According to the study conducted by Rajapaksha *et al*. [15] in Sri Lanka, the annual gross production of fruits and vegetables is being utilized in 55-60 % for local consumption, 11% for exportation. And the remaining 30-40 % is considered to be wasted due to improper post-harvest practices and post-harvest decay. And also this study has identified several contributing factors for this estimated post-harvest loss. Potential gaps between fresh chain market operations, lack of awareness, lack of a well-coordinated cold chain process, lack of government intervention, lack of resources and technology are the identified factors that cause a higher post-harvest loss in this study.

5. Nutritional and chemical composition

Several studies have reported the nutritional and chemical composition of pumpkins; in different varieties of the same species, in different species of pumpkins and in different parts of pumpkins. According to a study conducted by Hashash *et al*. [25] in Egypt using *C. pepo* L. fruits, fruit pulp and seeds, they have reported the proximate nutritional composition, mineral composition and anti-oxidant activity of each fruit part. According to the study results, carbohydrate content of all three parts were considerably high as 14.51, 9.22 and 10.93 % in fruit flesh, pulp and the seeds, respectively. And also moisture contents of fruit pulp and flesh were reported as higher than 70 % where in the seeds, the moisture content was relatively less as 5.63 %. In addition to these, fat and protein contents of seeds have reported as the highest values as 33.4 and 39.5 %, respectively. These reported values by this study have confirmed the role of pumpkins in addressing different dietary concerns. In this study, mineral analysis of different fruit parts has also done and seeds have reported as the best source of minerals compared to the fruit pulp and the flesh. In the β carotene analysis, fruit flesh and pulp have reported the highest values as 37.83 and 34.75 µg/g, respectively. This has confirmed the use of pumpkin fruit flesh as a promising anti-oxidant agent.

In a study conducted by Hussain & Jamil [38] using *C. maxima* fruit flesh, peel and seeds, they have identified the anti-oxidant and anti-microbial compounds available in the tested fruit parts. The anti-oxidant activity has been assessed by DPPH (2,2-diphenyl-1-pichrylhydrazil) radical scavenging method using the 80 % methanolic extract of dry powders of each part. In this, they have reported a higher scavenging activity for the seed extract where the lowest value was

reported regards to the flesh extract. According to the results, peel powder had 13.00 mg AAE per 100 g where this value was 10.58 and 16.53 for flesh and seed powders, respectively. And also in this study they have tested anti-microbial activity of these extracts by the inhibition zone calculations. Under that, all three types of extracts have shown a greater anti-fungal activity against four fungal pathogens and a significant anti-bacterial activity against four different bacterial pathogens.

A study was carried out in Bangladesh [11] to identify the nutrient components in different parts of indigenous and hybrid varieties of *C. maxima* including seeds, peel and flesh. According to this study, a significant difference was not reported between the two varieties relative to the moisture, crude fibre, ash and fat in flesh and peel samples. But there was a significant difference in the total proteins and carbohydrates in the seed samples of the two varieties. And also according to this study, it has proved that the seeds of the hybrid variety has enriched with crude fibre and carbohydrates as 52.37 mg/100g and 14.54 mg/100g, respectively. Another study which was carried out by Shahangir [39] in order to identify the nutritional composition of *C. maxima* seeds and the seed crude oil has also reported approximately similar values compared to the previous study. In this study, total lipid was identified as 36.7 % which was then extracted and developed in to crude seed oil. The lipid composition of the seed oil has analysed by Gas-Liquid Chromatography (GLC) technique and according to results, oleic acid was the main component in the extracted seed oil with 40.58 %. And also palmitic, linoleic and stearic acids were detected in minor amounts.

According to a study conducted by Blessing *et al*. [40] using 10 different *Cucurbita* spp. accessions available in Nigeria, they have found that there was a significant difference between the selected accessions in their total protein content, carbohydrate content, crude fibre content and β carotene and lycopene contents. And also the study has reported that the values obtained for the β carotene and lycopene contents which were ranging from 0.72-2.48 mg/100g and 0.487–1.988 mg/100g, respectively were approximately similar to the values obtained relative to Tomato.

In another study conducted by Zhou *et al*. [24] which was a comparative study of anti-oxidant activity of three different pumpkin species including *C. maxima, C. moschata* and *C. pepo*, they have identified a anti-oxidant composition and anti-oxidant activity variation between the three species. In the study they have determined the L-ascorbic acid, total flavonoids, total phenols and β carotene contents in three selected pumpkin species. According to results of this study, *C. maxima* has shown the highest value for total flavonoids and β carotene where the moschata and pepo had shown relatively lower values. And also the study has stated that, a significant difference was not observed in the total phenolic content in maxima and moschata types where the pepo had a relatively lower value compared to the other two types. And also the L-ascorbic acid content in maxima was significantly higher than the other two types according to the study results. Another study was conducted by Mohaammed *et al*. [30] using *C. maxima* flesh, seeds and peel in order to identify the types of anti-nutrient compounds found in different fruit parts. According to that oxalates, saponins, alkaloids, cyanides, tannins and phytates were the types of anti-nutrients that they have reported.

A study conducted by Ghosh & Rana [29] was reported the physicochemical, nutritional and bio-active compounds and fatty acid profiling data of *C. maxima* flowers. According to this study, the proximate composition of the flower was reported as 3.1, 0.15, 2.23 and 4.53 % for ash content, fat, protein and fibre content, respectively. And also they have identified that there were characteristic bio-active compounds in both aqueous and methanolic extracts of pumpkin flower. Flavonoids and glycosides were only found in the aqueous extract where phytosterols and terpenoids were found in the methanolic extraction. And under the fatty acid profiling part of this study, they have identified that there were different saturated fatty acids like lauric, capric, myristic acids and two monounsaturated fatty acids as palmitoleic and oleic acids and linoleic acid as the only polyunsaturated fatty acid in pumpkin flowers.

6. Potential benefits of pumpkin consumption

6.1. Nutritional aspects

Several nutritional and phytochemical analysis have reported the composition of different parts of pumpkin fruit for their high protein content, Vitamin A, E and C content, β carotene content, phenolic content, crude fibre content, minerals, fat content and carbohydrate content. According to Hussain Dar *et al*. [2], pumpkins are considered as a good source of calories due to the high carbohydrate content of them. And also this study has reported that high amount of protein and minerals in pumpkin makes it an important source of proteins and minerals like iron, magnesium, sodium, potassium. Another study done by Cantwell [35] has stated that pumpkins are rich in β carotene; which gives its characteristic yellow-orange colour, is the main precursor of Vitamin A that makes pumpkins a potential source of Vitamin A.

6.2. Nutraceutical aspects

A study conducted by Salehi *et al*. [41] has stated that *Cucurbita* spp. has been used in several folk medical practices in treating gastro-intestinal diseases and intestinal parasites. In the study conducted by Hussain Dar *et al*. [2], the nutraceutical importance of pumpkin has been outlined. According to that, pumpkin seeds have an anthelmintic effect and proved its effectiveness in treating bladder disorders. And also pumpkins are considered to be anti-diabetic, anti-carcinogenic, anti-inflammatory, hypolipidemic agent and effective in postmenopausal women in maintaining the hormonal balance in the body [2,42].

7. Development of value-added products

Various studies have conducted to develop value-added products including dietary supplements and food additives using different parts of the pumpkin fruit. In a study conducted by Malkanthi & Hiremath [43], it has identified the effectiveness of using pumpkin pulp flour as a supplement in string hopper production. According to this study, different ratios of pumpkin pulp flour as 0, 5, 10 and 20 % have mixed with rice flour and through a sensory evaluation, consumer acceptability of these items was checked. As the study states, the best combination of flour was the 20 % pumpkin flour incorporated item with 8.13 overall acceptability. And also according to the results of the proximate analysis of this resulted product, it has confirmed that the supplementation of pumpkin pulp flour into rice flour has elevated the protein content, carbohydrate content, moisture content, crude fibre content, mineral composition and anti-oxidant compounds in the end product.

According to a study carried out by Mishra *et al*. [44], they have developed two Indian traditional recipes known as 'Halwa' and 'Mathri' using pumpkin seed flour instead of the conventional ingredient; wheat flour. And a sensory evaluation has been conducted in order to evaluate the consumer acceptance. As a result, Mathri had identified as the most accepted item compared to Halwa by the participants. And the proximate analysis conducted for Mathri, has confirmed that the nutritional composition is higher in the end product resembling the higher nutrient composition in pumpkin seeds.

Another study was conducted by Kumari *et al*. [45] to identify the nutrient composition and the consumer acceptance of biscuits which has developed as a value-added product by incorporating germinated pumpkin seed flour in different concentration to wheat flour. Here they have incorporated 10, 20 and 30 % of seed flour into wheat flour in biscuit production. During the sensory evaluation, all three types of biscuits have been accepted by the consumers at 'like very much' category. And also the proximate analysis has confirmed that the elevation of the moisture content, mineral content, crude fibre, fat content, Vitamin C content and β carotenes in the end product in all three pumpkin seed flour supplemented biscuits where the total protein content and carbohydrate content have declined. As the reason for this result, they have stated that incorporation of pumpkin seed flour reduces the amount of wheat flour content in the biscuits which makes the reduction of proteins and carbohydrates, as wheat flour contains more proteins and carbohydrates than pumpkin seed flour. Another study conducted by Khan *et al*. [46] has reported similar results as in the previous study where wheat flour has substituted by pumpkin flour in biscuit production.

According to a study conducted by See *et al*. [47], the use of *C. moschata* fruit flour in bread making has been evaluated. And under this study they have supplemented different ratios of pumpkin flour as 5, 10 and 15 % in bread production. According to the results of the proximate analysis and the physical property check in the end product, the moisture content of the bread has increased along with the crude fibre, minerals content. But the carbohydrate, protein and fat contents has reduced in the end product because wheat flour contains more fat, proteins and carbohydrates than pumpkin flour. Under this study, a sensory evaluation also has been conducted in order to identify the consumer acceptance for the developed bread types. According to the results of that, the highest score has received by the bread prepared with 5% pumpkin flour incorporation.

A study which has analysed the physicochemical properties of cake made by pumpkin flour was done by [48]. According to this study pumpkin blended cakes was made by mixing different ratios of pumpkin flour as 5, 10 and 15 % to substitute wheat flour content. During the proximate analysis of the end products, results reflected that the moisture content was increased in the end product and it was highest in the sample with 20 % pumpkin flour. Similarly, the mineral content, fibre content and protein content were higher in the supplemented cakes and the values were highest in the sample with highest pumpkin flour content. But results have shown that the lowest fat content and carbohydrate content were reported in this sample due to the replacement of wheat flour in them. Under this study, a sensory evaluation has conducted and according to its results sample prepared with 5 % pumpkin flour had the highest overall acceptability where the highest pumpkin flour supplemented cake had the lowest acceptability by the panellists.

In addition, another study conducted by Toro-Velez *et al*. [49] has reported the production of packaged pumpkin flowers of *C. pepo* and *C. moschata* as a dietary supplement. Under this study, they have tested two different packaging systems including passive and active modified atmosphere packaging (MAP) to identify the most effective packaging method that will ensure the quality and the nutritional composition of pumpkin flowers. According to the results of this study, around 27 % of the packaged flowers were deteriorated at the end of the 5th day after packaging in both ways as active and passive MAP. According the sensory evaluation conducted to identify the consumer acceptability of these developed products, fresh flowers received the highest ranking in the 'like very much' category where the both packaged flowers were ranked in the 'moderately like' category.

According to the study conducted in Sri Lanka by Arachchige *et al*. [50], extruded snacks were developed using pumpkin flour. Pumpkin flour has prepared by using a high flesh and seeds containing pumpkin variety to receive a maximum flour yield. For the snack production they have used wheat flour, pumpkin flour, salt, onion powder and spices as the dry ingredients where vegetable oil, water and shortening flavours as the liquid ingredients. Extruded snacks were prepared by using the twin screw extruder and the final product was then packaged in aluminium coated PET (Polyethylene Terephthalate) according to the modified atmosphere packaging aspects. Another study which was conducted by Sanadarani & Prasadi [51] to extract pectin as a value added product from *C. maxima* waste has reported the physiochemical properties of the extracted pectin from different parts of pumpkin. Pectin extraction was done by acid hydrolysis method and the highest yield of pectin was extracted from the peel which was 2.91 %, compared to the flesh and pulp parts of the fruit. According to the proximate analysis of the extracted pectin from pumpkin, the moisture content was reported within the acceptable level as below 12 % where the ash content was lower in the pumpkin pectin than the level in commercially available pectin. And also the solubility of the extracted pectin was almost similar to the solubility of commercially available pectin in cold water, hot water, cold alkali and hot alkali. The results of this study have highlighted the effectiveness of using the extracted pectin from pumpkin as a gelling agent and a thickener in jam and jelly production.

8. Conclusion

Cucurbita spp. is a mostly overlooked yet an underutilized crop in the world. Multiple studies have confirmed the high nutritional and chemical composition of pumpkin which makes it an ideal dietary source. Nutritional composition and the chemical composition can be varied depending on the species, variety, growth conditions, harvesting time and also on the post-harvest management strategies. Due to the significant imbalance between the pumpkin production and the consumption, the post-harvest loss has caused a significant loss in world's pumpkin production. The current findings confirm the importance of utilization of pumpkin through development of value added products as a post-harvest management strategy and as a way of creating a market for the products with beneficial nutritional and nutraceutical properties. This review markedly highlights the details about the current pumpkin production, nutritional and chemical composition in different cucurbits, post-harvest loss and management and value additions according to the literature. This further strengthens researchers to identify the gaps between the existing knowledge and especially provides opportunities in applying the knowledge in developing pumpkin based value added products.

Compliance with ethical standards

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Disclosure of Conflict of interest

All authors (K.O.G. Himani Ruwanthika, M.L.A. Mayuri S. Munasinghe, and R.A. Upul J. Marapana) declare no conflict of interest.

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