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Comparative study on physical characteristics and nutritional composition of pumpkin (*Cucurbita moschata*) at different stages of maturity

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Present day scientists are paying more attention towards developing new value-added products from underutilized crops for economic growth in agriculture system. Therefore, present experiment was undertaken to explicate the nutritional potential of pumpkin (*Cucurbita moschata*) at different stage of maturity until it is fully mature and ripe. Variation in different physico-biochemical properties, for example moisture content, sugars, titratable acidity (TA), crude proteins, crude fat, *β*-carotene, ascorbic acid, pectin and fibre in flesh, peel and seeds of fruit provides the better understanding for its utilization in preparation of various products. The firmness of pumpkin increased from 4.94 lbs/inch^2 at 15 DAA (Days after antesis) to 22.50 lbs/inch^2 at ripe stage during maturity. *β*-carotene content of flesh increased from 1.34 to13.30 mg/100g and 26.26 while quantity ascorbic acid in flesh of fruit declined from 26.46 to 13.16 mg/100 g at 15 DAA to ripe stage. In seeds crude fat increased from 5.43 to 50.24% and protein increase was found to be from 4.10 to 19.56%. Pectin content (as calcium pectate) of flesh and peel increased from 0.56 to 1.89 and 0.78 to 2.15%, respectively from 15 DAA to 45 DAA and at later stage it decreased. The knowledge about physico-chemical quality of pumpkin at different stage of maturity would help in selecting right stage of fruit maturity for its utilization in acceptable manner.

Keywords: Chemical composition, Days after anthesis, Flesh, Maturity, Peel, Pumpkin, Seed

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Pumpkin belongs to genus *Cucurbita* of the family Cucurbitaceae which includes squashes, cantaloupes, cucumber, watermelon and gourds. These gourd squash includes around 119 genera and 825 species[1], derived from tropical and subtropical regions and out of which 26 species are cultivated as vegetables[2]. Like other squashes, pumpkins are native to North America. The name pumpkin originated from a Greek word "Pepon", which means large melon[3]. At present, pumpkin is grown throughout the tropical and sub-tropical countries of the world. Worldwide, *C. pepo*, *C. maxima* and *C. moschata*, are the three common types of pumpkin. *Cucurbita moschata* is the most common variety of pumpkin in Asia and United States and is widely cultivated since prehistoric time[4]. The total production of squashes, gourds and pumpkin in the world is 25.19 million tonnes[5]. India produces 1,197 million tonnes of pumpkin and other squashes, from an area of 54000 ha[6]. Uttar Pradesh, Chhattisgarh, Jharkhand and Tamil Nadu are the major pumpkin producing states of India[6].

Cucurbita moschata is a monoecious, creeping, vine-like annual that trails along the ground or climbs by tendrils. They grow in warm to tropical climates with sufficient moisture. It is a crop that requires soil temperature (30 inches deep) of at least 60°F (15.56°C) and soils that hold water well. Leaves of *C. moschata* are simple, alternate and shallowly lobed, often with white spots along the veins. Single axillary flowers (male typically long-stalked with three stamens and female typically short-stalked with 3 two-lobed stigmas) are creamy white to orange-yellow and bloom in late spring. Male and female flowers are present on the same plant and bear pollen and ovary, respectively. The flowers are short-lived and often close by mid-morning[7]. Native and honey bees are normally able to complete pollination. Stalks have the tendency to thicken at the sites where the fruits appear[8].

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Pumpkin crops reach maturity at about 75 to 180 days after sowing, depending on season and other conditions[9]. They are harvested at fully mature stage when the stalk becomes cracked and corky. Rind (skin) of pumpkin at harvesting stage should be hard enough which can resist the pressure or entry of fingernail and thumb as well as make a 'crisp' sound when it breaks the skin[10]. Fruits are often allowed to remain in field till vines are dried during summer months or killed by frost during winter months[11]. Pumpkin should be allowed to attain full size and maturity of seeds and rind before harvesting. While harvesting the fruit by cutting it off the vine with a sharp knife, 3-6 inches of the stem must be attached to the fruit. This makes the fruit look more attractive and less likely to be attacked by fruit rot pathogens at the point of stem attachment. The squash of *Cucurbita moschata* is extremely variable in morphology of fruits and seeds due to large genetic variation within the species. Fruits are relatively large, with shapes ranging from globose to oblong to flat. The surface of the fruit is smooth or with rounded ribs, rarely varicose or granular.

Pumpkin is utilised for its leaves, marrow, fruit pulp and seeds and are all appropriate resources for multifarious food. Unripe, still small and green pumpkin is eaten in the same way as zucchini. When ripe, the pumpkin can be boiled, baked, steamed or roasted and can be frozen or canned. Over the past countless decades, researchers have engrossed their work on the scientific assessment of nutritional components of pumpkin and squashes, which has been frequently led to its utilization as a functional food or exploitation in medicines in several epidemiological studies[12]. On an average, the flesh portion, peel and seed of ripe pumpkin is 78.69%, 17.95% and 3.63%, respectively. While, it comprises of 82.58% moisture, 7.29% protein, 0.383% fat, 1.26% pectin, 2.34% crude fibres, 16.78 mg per 100 g ascorbic acid and 13.30 mg per 100 g β-carotene of edible portion at ripe stage[4]. The pumpkin pulp comprehends various minerals like sodium, potassium, calcium, iron and phosphorous. Fresh seeds of *Cucurbita moschata* contain moisture, 28.5%; protein, 37.7%; and ash, 4.4%; whereas, dried pumpkin seeds contain moisture content of 5.6%, protein content of 37.4% and ash content of 4.4%[13]. Pumpkin contains bioactive materials such as protein-bound polysaccharides, carotenoids, minerals, amino acids and active proteins.

Pumpkin is an important horticultural crop in terms of nutrition but has not received much attention for its commercial cultivation. The people of the rural areas of India have been growing it on the roofs of the house or in the backyard of the house using their traditional knowledge. In Himachal Pradesh, the ripe pumpkin is utilized in preparation of traditional dish (sweet or savoury) during *Himachali* weddings and festivals. Whereas, in Kerala, they used in preparation of *ellisserry* and *olan* (prepared using red cowpea and ripe pumpkin). Since, India has high proportion of low-income group that requires balance diet at affordable price. In such case, this low-cost crop can serve as good source of nutrition for weaker section of the society. In addition, lot of efforts has been done to convert pumpkin profitably into various value-added products. Pumpkin can be used in the production of various products such as jam, jelly and marmalade, candy, puree, sauce, chutney, pickle, squashes[14], RTS[15], dried slices, cubes and osmo-dried cubes[16], intermediate moisture food[17] and instant food mixes such as *halwa* and soup[18]. These value-added products could serve as new source of employment for the youth and women of village, hence, being highly potential crop of future.

Therefore, the present investigation has been undertaken to elucidate the physico-chemical changes that occur in different portions of pumpkin at different stages of maturity and ripen stage. This could provide better understanding of the crop for enhancing its utilization and will also assist in selection of fruit at appropriate stage of development for product development.

Methodology

Plant material

In the present study, *Cucurbita moschata* was grown in the field of Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India and were collected to evaluate the physical and nutritional characteristics of pumpkin at different stages of maturity and at ripen stage. The fruits of pumpkin were collected at five sequential stages of development i.e., 15, 30, 45 and 60 Days After Anthesis (DAA). The fruit harvested after 60 DAA were stored in the laboratory at room temperature and were utilized for evaluation at ripe stage (till the whole surface colour of fruit changes from yellow to orange). The detail of harvesting stage is presented in Table 1 and Figure 1a and 1b.

Pumpkins harvested at particular stage of maturity were brought to the Fruit Processing Research Laboratory of Department of Food Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India. They were analysed for various physical characteristics and nutritional composition.

Table 1 — Detail of pumpkin harvested at different stages of maturity

Harvesting stage (DAA*)	Code (M)
15 DAA	M_1
30 DAA	M_2
45 DAA	M_3
60 DAA	M_4
Ripe	M_5

DAA*: Days After Anthesis

Physico-chemical analysis

The selected fruits were brought to the Fruit Processing Research Laboratory of Department of Food Science and Technology, washed thoroughly in tap water and air dried. The fruits were analysed for physical characteristics such as weight (g), diameter (cm), length (cm) and firmness (lbs/inch^2). Later, the fruit was divided into three different portions viz.,

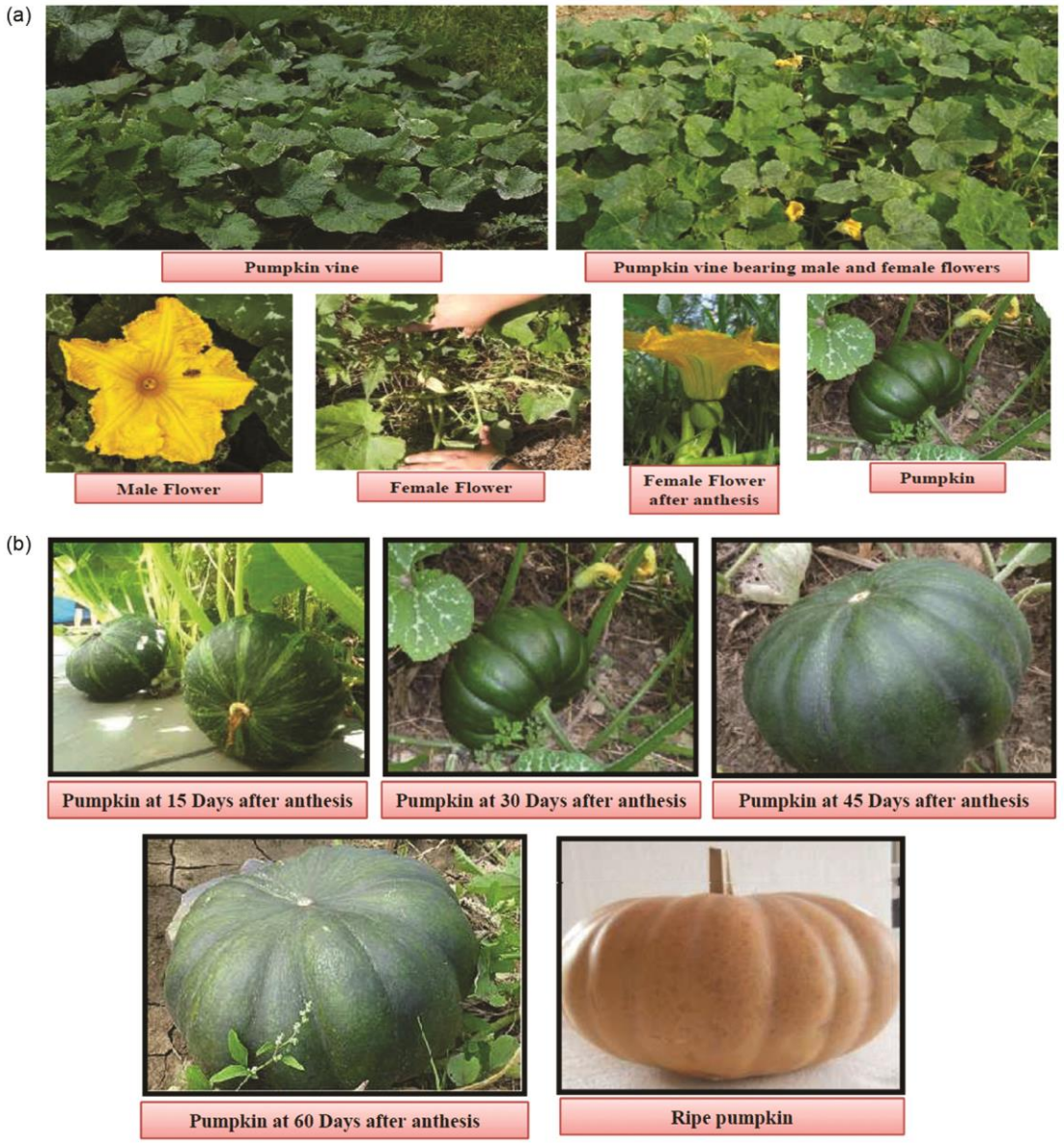

Fig. 1a — Glimpses of field trail showing the raising of crop for harvesting pumpkin (*Cucurbita moschata*) at stages of maturity; (b) Pumpkin at different stages of maturity

Flesh, peel and seed. These portions were analysed for visual colour, recovery (%) and various nutritional compositions.

The nutritional composition was determined as per the standard procedures. Moisture content, total soluble solids, ash content and crude protein were analysed by AOAC[19]. However, titrable acidity, pH, sugars, *β*- Carotene, crude fat and pectin were determined by Ranganna[20]. Crude fibre was analysed by method described by Gould[21].

Statistical analysis

All the experiments were run in triplicate. The data on physico-chemical characteristics of pumpkin fruits were analysed by using Completely Randomized Design (CRD) as given by Cochran and Cox[22] and their significant levels were determined at $p<0.05$.

Results and Discussion

Evaluation of pumpkin at different stages of maturity for physico-chemical analysis

Pumpkins harvested at different stages of maturity were analysed for various physico-chemical properties.

Changes in physical characteristics

The physical characteristics of pumpkin (*Cucurbita moschata*) harvested at different stages are represented in Table 2. An appraisal of data indicated the diameter and length of pumpkin at 15 Days After Anthesis (DAA) to be 23.40 and 9.80 cm, respectively. The fruit diameter and length progressively increased to 60.90 cm and 34.60 cm, respectively at 60 DAA, with no change at ripen stage (Fig. 2). The average weight recorded at 15 DAA was 667.45 g which gradually increased with maturity having maximum value (3222.84 g) at 60 DAA (Fig. 3). However, at ripe stage the weight of fruit (3223.45 g) was found to be at par with pumpkin at 60 DAA. Similar trend in increase of diameter, length and weight of *Cucurbita maxima* was recorded by Sharma and Rao[23]. The researchers stated that the gain in weight of pumpkin is mainly due to increase in its diameter rather than the length. Further, this irreversible increase in dimension and weight of fruit

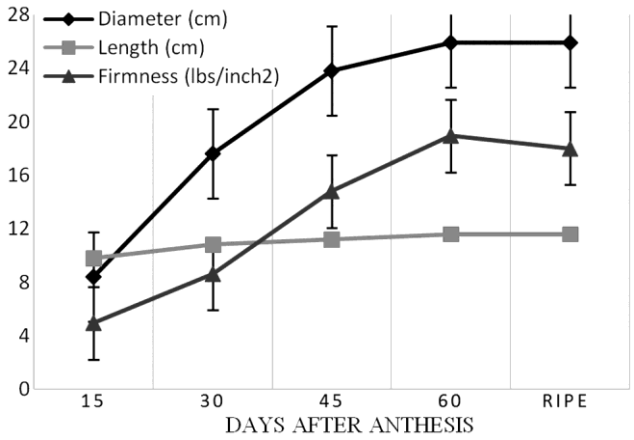

Fig. 2 — Effect of stage of maturity on diameter, length and firmness of pumpkin

Table 2 — Physical characteristic of pumpkin (*Cucurbita moschata*) at different stages of maturity

Characteristics \ Stage of Maturity		Days After Anthesis (DAA) 15	30	45	60	Ripe*	$CD_{0.05}$
Weight (g)		667.45	2312.90	2664.85	3222.84	3223.45	3.60
Diameter (cm)		23.40	34.60	42.80	60.90	60.90	0.36
Length (cm)		9.80	14.80	21.20	34.60	34.60	0.52
Firmness (lbs/inch^2)		4.94	8.63	18.78	20.93	22.50	0.23
Colour of different portions of pumpkin							
Flesh	Visual colour	Greenish white	White	White	Yellow	Yellow orange	-
Peel	Visual colour	Dark green	Green	Bright green	Light green	Pale yellow to orange	-
Seed	Visual colour	White	White	Cream	Cream	Cream	-
% Recovery (%) of different portions of pumpkin							
Flesh		88.06	85.33	82.09	78.44	78.40	4.78
Peel		11.04	13.15	15.14	17.95	17.99	0.39
Seed		0.90	1.51	2.77	3.63	3.63	0.10

Ripe*: The fruit harvested after 60 DAA were stored in the laboratory under room temperature till the whole surface colour turned yellow to orange.

is a consequence of cell division and cell elongation. Muenmanee *et al*.,[24] also have reported an increase in dimension and weight of pumpkin fruit (*Cucurbita maxima*) with increase in stage of maturity. It was also recorded in the present study that the rind firmness increased gradually and reached the highest value (22.50 lbs/inch^2) at ripe stage (Fig. 2). In contrary to present study Muenmanee *et al*.,[24] reported a bilateral result as the firmness increased from 4846.74 g at 10 Days after fruit set (DAFS) to 16884.60 g at 50 DAFS and a decline to 15831.93 g at 60 DAFS. Dhiman *et al*.[25] noticed a value of 21.3 lbs/inch^2 in ripe pumpkin. The increase in firmness of pumpkin might be due to reduction in moisture content, as fruits tend to lose its flexibility when water content decreases[26]. Our study confirms this reasoning, as it was observed that as the maturity stage increased moisture content decreased (Table 3 and 4). The increase in firmness of pumpkin may also be attributed to the pectin content which was also found to increase with the enhancement in maturity stage.

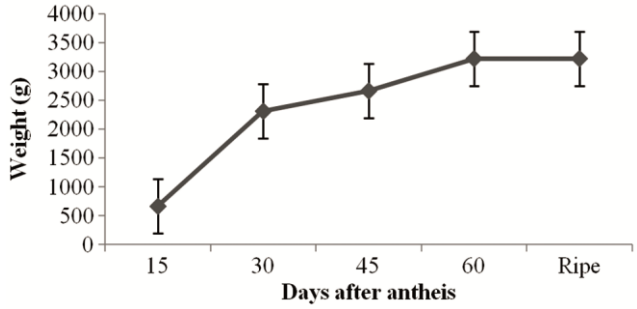

Fig. 3 — Effect of stage maturity on weight of pumpkin

Table 3 — Chemical characteristic of pumpkin (*Cucurbita moschata*) flesh at different stages of maturity

Stage of maturity / Chemical parameters	Days After Anthesis (DAA) 15	30	45	60	Ripe*	$CD_{0.05}$
Moisture (%)	93.00	88.00	85.00	82.58	81.53	0.82
Total soluble solids (°B)	4.46	6.83	9.13	11.35	11.90	0.18
Titrable acidity (%)	0.18	0.15	0.11	0.08	0.07	0.02
Total sugars (%)	1.30	1.75	2.46	3.90	4.19	0.15
Reducing sugars (%)	0.84	1.28	1.60	1.98	2.19	0.05
Ascorbic acid (mg/100 g)	26.46	24.79	21.48	16.78	13.16	0.06
β-carotene (mg/100 g)	1.34	4.22	5.69	7.89	13.30	0.09
Crude fibre (%)	0.50	0.86	0.94	1.34	1.65	0.02
Ash (%)	1.018	1.017	1.016	1.015	1.014	NS
Crude protein (%)	0.66	0.72	0.89	1.09	1.45	0.02
Crude fat (%)	0.06	0.16	0.20	0.38	0.40	0.01
Pectin (% calcium pectate)	0.56	0.94	1.89	1.80	1.63	0.05

Ripe*: The fruit harvested after 60 DAA were stored in the laboratory under room temperature till the whole surface colour turned yellow to orange.

Table 4 — Chemical characteristic of pumpkin (*Cucurbita moschata*) peel at different stages of maturity

Stage of maturity / Chemical parameters	Days After Anthesis (DAA) 15	30	45	60	Ripe*	$CD_{0.05}$
Moisture (%)	20.97	18.89	17.00	14.34	14.30	0.29
Total soluble solids (°B)	2.45	3.98	5.81	8.52	8.60	0.09
Titrable acidity (%)	0.11	0.10	0.09	0.06	0.05	0.01
Total sugars (%)	0.93	1.15	1.39	1.70	1.84	0.09
Reducing sugars (%)	0.24	0.49	0.61	0.84	0.89	0.05
Ascorbic acid (mg/100 g)	6.35	4.19	2.65	1.90	1.81	0.07
β-carotene (mg/100 g)	0.81	1.23	3.43	4.90	6.78	0.03
Crude fibre (%)	1.73	2.70	3.82	4.13	5.26	0.03
Ash (%)	1.34	1.33	1.32	1.31	1.30	NS
Crude protein (%)	0.19	0.61	0.74	0.93	1.24	0.03
Crude fat (%)	0.11	0.34	0.50	0.65	0.70	0.09
Pectin (% calcium pectate)	0.78	1.43	2.15	2.10	1.87	0.01

Ripe*: The fruit harvested after 60 DAA were stored in the laboratory under room temperature till the whole surface colour turned yellow to orange.

A lot of variation was noticed in colour of pumpkin peel and flesh during the fruit maturation and ripening. The flesh colour of pumpkin changed from greenish white to yellow orange colour right from 15 days of maturity to ripe stage. The colour of pumpkin peel started from dark green at 15 DAA and turned into light with little yellow tints at 60 DAA, while at ripe stage it turned to pale yellow to orange. The change in colour of peel and flesh during fruit ripening is due to the degradation of chlorophyll structure and formation and accumulation of β-carotene, α-carotene and lutein[27]. A very little change in colour of seeds (with seed coat) during fruit maturation and ripening was observed. At 15 DAA, seed colour was white which gradually changed to creamish at 45 DAA while thereafter it developed a brown lining surrounding the seed at ripe stage.

The data indicated a decrease in flesh recovery (Table 2 and Fig. 4) with increase in DAA. The maximum flesh (88.06%) was noticed in pumpkin at 15 DAA and minimum (78.40%) in pumpkin at ripe stage. The intermediate values were recorded at 30 DAA (85.33%), 45 DAA (82.09%) and 60 DAA (78.44%). The recovery of peel increased from 11.04% at 15 DAA to 17.99% in ripe pumpkin. The % recovery of seed ranged from 0.90 to 3.63% with increase in maturity stage from 15 DAA to ripe.

Changes in chemical characteristics of flesh

The chemical composition of pumpkin flesh at different stages of maturity is shown in Table 3. The changes observed in the chemical composition of pumpkin during maturation have been attributed to physiological, biochemical and molecular events which affect its nutritional and quality properties. The moisture content of pumpkin was highest (93.00%) at 15 DAA, which significantly decreased to 81.53% at ripe stage. There was significant increase in total soluble solids (TSS) from 4.46 (at 15 DAA) to 11.90 (ripe stage) B with increase in stages of maturity. The increase in TSS may be attributed to hydrolysis of starch into simple sugars[28]. The maximum titrable acidity (0.18%) was noticed in flesh of pumpkin at 15 DAA while the minimum (0.07%) was in pumpkin at ripe stage. The decrease in titrable acidity during fruit maturity may be due to the utilization of organic acids in the respiratory process and other chemical reactions. The total and reducing sugars of the pumpkin was found to increase from 1.30 to 4.19 and 0.84 to 2.19%, respectively as the fruit matures from 15 DAA and reaches to ripe stage. The scenario for total and reducing sugars was found to be coinciding with the increasing pattern of TSS. The increase in sugars during fruit development may be attributed to the breakdown of starch and other complex polysaccharides during sugar metabolism and catabolic processes into simple sugars such as glucose and fructose.

A perusal at the data of ascorbic acid reflected that the content at 15 DAA was 26.46 mg/100 g which was found to decrease up to 13.16 mg/100 g at ripe stage (Fig. 5). The loss of ascorbic acid during maturity and ripening of fruit might be due to conversion of ascorbic acid into sugars during respiratory process by the action of enzyme (ascorbic acid dehydrogenase) as has been reported by Ishaq *et al*[29]. The β-carotene content of pumpkin varied

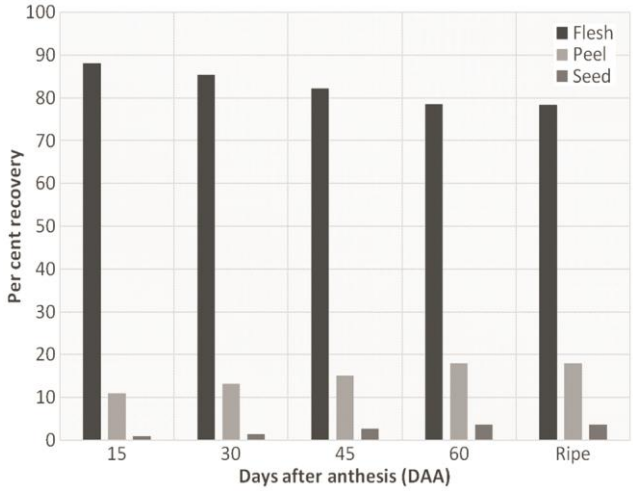

Fig. 4 — Effect of stage of maturity on recovery of flesh, peel and seed

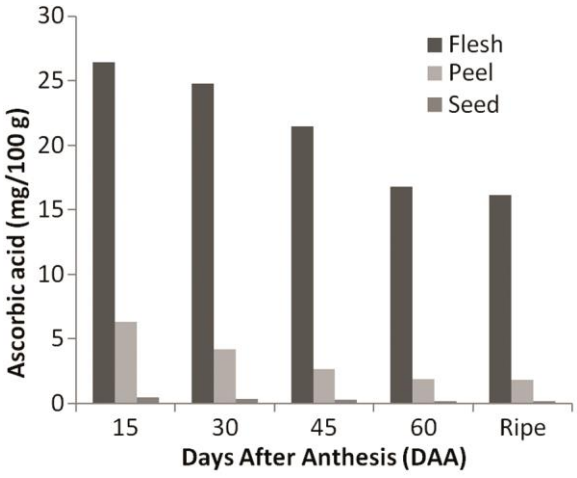

Fig. 5 — Effect of stage of maturity on ascorbic acid content of different portions of pumpkin

from 1.34 mg/100 g at 15 DAA to 14.30 mg/100 g at ripe stage (Fig. 6). The rapid increase in *β*-carotene of flesh has a direct relation to change in its colour as shown in Table 3. The increase in carotenoid contents might be due to accumulation of certain compounds (also known as carotenogenesis) during ripening stage of pumpkin fruit as stated by Sharma and Rao[24]. The amount of crude fibre, protein and fat was noticed to increase from 0.50 to 1.65, 0.66 to 1.45 and 0.06 to 0.40%, respectively with the advancement in stage of maturity.

Higher ash content (1.018%) was recorded in immature fruit at 15 DAA which decreased to 1.014% at ripe stage. This decrease in ash content during fruit development may perhaps owe to the high mineral absorption from soil during early developmental stages which are utilized in metabolic pathways. Dilution effect can also be attributed to the decrease in ash content as the fruits gain considerable weight during the latter stages of growth and development[30]. The maximum value of pectin as calcium pectate (1.89%) was found in fruit at 45 DAA, while minimum (0.56%) was at 15 DAA fruit (Fig. 7). The increase in pectin from 0.56% at 15 DAA to 1.89% at 45 DAA might be due to biosynthesis of pectin in cell wall and middle lamella. However, a slow decrease thereafter can be attributed to the action of enzymes during ripening of the fruits but the decrease was not very gradual, as the biosynthesis of pectin continuous in middle lamella during the latter stage of fruit development[31].

Changes in chemical characteristics of peel

An appraisal of data (Table 4) revealed that the moisture content of pumpkin peel decreased from 20.97% to 14.30% while there was significant increase in TSS from 2.45 to 8.60 °B with increase in stage of maturity from 15 DAA to ripe stage. The decrease in titrable acidity from 0.11 to 0.05% was recorded with increase in maturity stage. An increase from 0.93 to 1.84 and 0.24 to 0.89%, respectively was noticed in total and reducing sugars. A drastic decrease in ascorbic acid from 6.35 to 1.81 mg/100 g was noticed in peel of pumpkin with increase in stage of maturity (Fig. 5) while *β*-carotene was at (6.78 mg/100 g) at ripe stage and minimum (0.81 m/100 g) at 15 DAA (Fig. 6). A significant increase in crude fibre (1.73 to 5.26%), protein (0.19 to 1.24%) and fat (0.11 to 0.70%) content of pumpkin peel with increase in maturity stage was

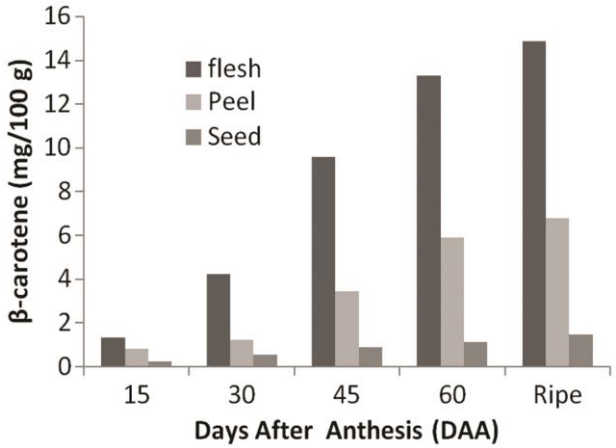

Fig. 6 — Effect of stage of maturity on *β*-carotene of different portions of pumpkin

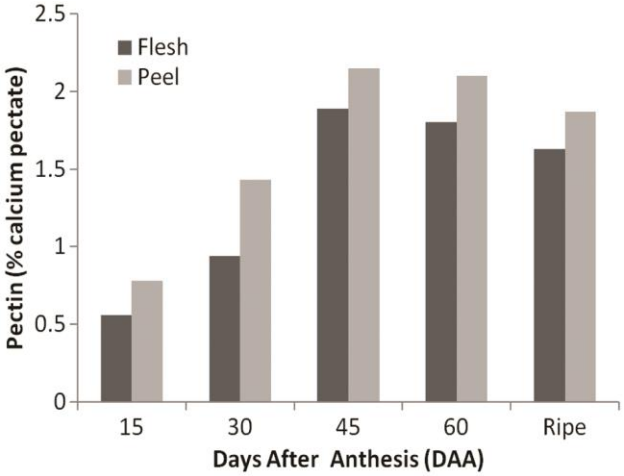

Fig. 7 — Effect of stage of maturity of pumpkin on pectin content of flesh and peel

recorded. The maximum pectin (as calcium pectate) was observed in pumpkin (Fig. 7) at 45 DAA (2.15%) followed by 60 DAA (2.10%) and ripe pumpkin (1.87%).

Changes in chemical characteristics of seeds

Table 5 highlights the chemical characteristics of seed of pumpkin (*Cucurbita moschata*) at different stages of maturity. With increase in stage of maturity from 15 DAA to ripe stage, the moisture content, titrable acidity and ash content decreased from 9.18 to 4.87, 0.08 to 0.03 and 5.16 to 5.12%, respectively. However, a significant increase in TSS (1.25 to 2.20°B), total sugars (0.28 to 0.83%), reducing sugars (0.07 to 0.54%), *β*-carotene (0.25 to 1.12 mg/100 g), crude fibre (2.81 to 8.19%), protein (4.10 to 19.56%) and fat (5.43 to 50.24%) were noticed with advancement of stage of maturity.

Table 5 — Chemical characteristics of pumpkin (*Cucurbita moschata*) seed at different stages of maturity

Stage of maturity / Chemical parameters	Days After Anthesis (DAA) 15	30	45	60	Ripe*	$CD_{0.05}$
Moisture (%)	9.18	7.57	6.20	4.90	4.87	0.19
Total soluble solids (°B)	1.25	1.73	2.03	2.19	2.20	0.01
Titrable acidity (%)	0.08	0.07	0.06	0.04	0.03	0.01
Total sugars (%)	0.28	0.36	0.47	0.70	0.83	0.03
Reducing sugars (%)	0.07	0.14	0.25	0.43	0.54	0.05
Ascorbic acid (mg/100 g)	0.48	0.38	0.29	0.18	0.15	0.01
β-carotene (mg/100 g)	0.25	0.56	0.89	1.12	1.45	0.03
Crude fibre (%)	2.81	3.17	5.90	7.85	8.19	0.09
Ash (%)	5.16	5.15	5.14	5.13	5.12	NS
Crude protein (%)	4.10	10.16	13.87	15.06	19.56	0.92
Crude fat (%)	5.43	11.14	34.40	47.89	50.24	0.30

Ripe*: The fruit harvested after 60 DAA were stored in the laboratory under room temperature till the whole surface colour turned yellow to orange.

Conclusion

The present investigation was able to indicate the effect of maturity phases of pumpkin on various physico-chemical parameters, with additional importance on the nutritional potential of fruit throughout its development stage. The outcome of the study reflected that with increase in days after anthesis *i.e.*, as the fruit reaches ripen stage, there is increase in *β*-carotene and total sugar along with crude fiber. The amount of *β*-carotene is high in flesh followed by peel while seeds are rich in crude fat and protein. The ascorbic acid content of flesh, peel and seed decreases with maturity. Thus, the experiment laid out enabled us to have improved understanding of such nutritionally rich, unexploited and underutilized raw material for better utilization. The fruit also contains pectin in reliable quantity at 45 DAA which could be utilized for its extraction other than product development. Since pumpkin is produced in large quantity in India, this fruit can be an alternative source of raw material that can be used for pectin extraction along with other raw material.

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Conflict of Interest

Authors hereby declare that there is no conflict of interests in this paper.

Authors' Contributions

Data curation, Formal analysis, investigation, writing original draft was done by PR. Conceptualization of work to be done, its administration and supervision was by AKD and SA. Whereas field trail was conducted under thorough guidance of AV. SR and SS guided PR during the drafting of the work and critically revised the content of manuscript for presenting intellectual content.

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