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Research Article

Nutritional and Phytonutrient Analysis of QPM and Normal Maize Inbred Lines

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ABSTRACT

Investigations were carried out to characterize twenty maize inbreds at biochemical levels among QPM and normal maize lines for their effective utilization in the breeding program. Proximate analysis was carried out to study the nutritional quality of maize inbred lines based on lysine and tryptophan levels among the two groups. The nutritional composition includes lysine, tryptophan, moisture, oil, crude protein, starch and total soluble sugars, showing significant differences between QPM and normal maize inbreds, while fibre and total ash content showed little variation. Phytonutrients showed slightly higher value for QPM lines compare to normal lines exhibiting good antioxidant capability of QPM lines. The present investigation highlights the importance of evaluating biochemical parameters when selecting parents for crossing programs. The proximate composition and antioxidant capacity were proved to be useful for nutritionally better varietal identification and to evaluate QPM and normal maize lines based on nutritional and antioxidant performance.

Keywords: *Maize, lysine, tryptophan, proximate composition, phytonutrient antioxidant.*

INTRODUCTION

Zea mays (L.), or maize in scientific parlance, is one of the world's most important grain crops essential to human and animal nutrition (Erenstein et al., 2022, & Hossain et al., 2023). Though it is thought to have originated in the Americas, maize has developed into a staple food crop grown widely in various temperatures and geographical areas. Its importance stems from both its adaptability and versatility, as it may be used to make industrial products, animal feed, and primary nourishment.

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In addition to providing vital nutrients like vitamins, fiber, and carbohydrates, maize is a staple food in many cuisines and is significant to many economically and culturally communities (Farhad et al., 2009). Because of its great yield potential and capacity to adapt to various environmental circumstances, maize is a key crop in tackling global food security challenges and sustaining agricultural economies worldwide. Cereal endosperm proteins are deficient in essential amino acids such as lysine and tryptophan and generally contain 1.5– 2.0% lysine and 0.25–0.5% tryptophan. However, 5.0% lysine and 1.1% tryptophan are required for optimal human nutrition (Young et al., 1998).

The importance of maize as a staple food crop cannot be overstated, yet its nutritional profile raises concerns regarding essential amino acid deficiencies. Maize is notably deficient in two crucial amino acids, lysine and tryptophan, which are essential for human health but present in limited quantities in this cereal. The inadequate levels of these amino acids in maize can lead to nutritional imbalances, particularly in regions where maize serves as a primary dietary component. Lysine and tryptophan are vital for synthesising proteins and properly functioning various physiological processes within the human body (Prasanna et al., 2001). Understanding and addressing the challenges associated with essential amino acid deficiencies in maize are essential steps towards improving the nutritional quality of this widespread and vital crop. Efforts in breeding programs and biotechnological interventions aim to enhance the amino acid content of maize, ensuring its continued role in providing a well-rounded and nutritionally rich food source for diverse populations. Maize is the first amongst the cereal crops to develop and release biofortified varieties. Several Quality Protein Maize (QPM) varieties, with enhanced content of essential amino acids, particularly lysine and tryptophan, have been deployed in SSA, Latin America and Asia (Atlin et al., 2011; Nuss & Tanumihardjo, 2011; & Prasanna et al., 2001).

As the global demand for maize continues to rise, assessing and enhancing the quality and quantity parameters of maize germplasm for sustainable agricultural practices becomes imperative. Efficient screening of maize germplasm for both quality and quantity traits is essential for developing cultivars that can meet the growing demands of an expanding population while ensuring nutritional adequacy. The integration of advanced breeding techniques, biotechnology, and precision agriculture in the evaluation process is vital to accelerate the development of maize varieties with improved traits, ultimately addressing the dual challenge of food security and nutritional quality.

MATERIALS AND METHODS

Plant material: Twenty maize inbred lines, consisting of two groups, viz., QPM and normal maize lines, obtained from the Main Maize Research Station, Anand Agricultural University (AAU), Godhra, Gujarat, were used for the nutritional quality and phytonutrient study. The present work was conducted at the Department of Biochemistry, B. A. College of Agriculture, AAU, Anand. The details of the inbreds analyzed in the present investigation are described in Table 1.

Proximate composition

For the determination of lysine content, the colorimetric method designed by Tsai et al. (1972) was followed. Tryptophan was determined using the method described by Hernandez and Bates (1969). Moisture content was estimated as per procedure developed by A.O.A.C. (Anon, 1980) using randomly selected maize grains from each replication. Oil was determined by ether extract method using Soxhlet apparatus. Percent of fat in the sample was calculated as under:

Oil (%) = (Wt. of the beaker + Ether extract) – (Wt. of the beaker)/ Wt. of sample x100

The procedure of Kuan et al. (2011) in maize inbred lines was used to determine starch, with some modifications. Total soluble sugars from the maize seed powder were determined using the phenol sulphuric acid method, as described by Dubois et al. (1956).

Crude protein (g N x 6.25/kg) was determined by a conventional macro-Kjeldahl procedure using mercuric oxide as a catalyst during digestion and trapping the ammonia in a saturated boric acid solution (Bailey, 1972). Ash content was determined using the method described by Sadasivam and Manickam (1992). The crude fibre was determined by treating an oil-free sample with sulphuric acid (0.26 N) and potassium hydroxide (0.23 N) solution in a refluxing system, followed by oven drying and muffle furnace incineration (AOAC, 1984).

Phytonutrient antioxidants

Estimation of total phenols was carried out by extraction with 80% rectified spirit. A standard curve was prepared from Catechol, and then total phenol content was estimated according to the method of Bray and Thorpe (1954). Estimation of carotenoid content was determined using the method described by Mishra and Gupta (1998). The antioxidant activity of the maize powder was determined according to the method developed by Nenadis et al. (2004) modified for a microplate using 2,2′-azinobis (3-ethyl-benzothiazolin,6-sulfonic acid) (ABTS).

Data analysis and Correlation analysis

Mean value and standard deviation (SD) were calculated. Pearson correlation coefficient analysis was carried out using the bivariate correlation tool of SPSS statistics 17.0 version, and their significance levels were calculated for linear regression analysis.

RESULTS

The proximate composition of twenty maize inbred lines analyzed are presented in Table 2. The moisture content ranges from 5.13 - 14.5 per cent among the two groups, viz., QPM and normal maize lines. As low moisture content is important for keeping the quality and shelf life of seeds, all high tryptophan-containing QPM lines showed higher moisture content ranging from 8.48 - 14.26 per cent, while normal maize showed lowered moisture content ranging from 5.13-9.64 per cent. Oil content varied between 2.33 - 5.95 per cent in twenty maize inbred lines with standard check HQPM-1 reported the significantly higher value of 5.95 per cent with QPM lines ranged from 4.80 – 5.95 per cent while normal maize ranged from 2.33 - 5.18 per cent.

Protein is the second largest bio-molecule of kernel which is stored in endosperm. Crude protein was found to be between 9.42 to 13.64 per cent along with significantly higher value of protein content was observed in HQPM-1 (13.64 %) which showed QPM lines were found to have higher crude protein ranged from 12.35- 13.64 per cent compare to normal maize inbred lines ranging from 9.42-12.11 per cent. Starch, a complex carbohydrate, is the main structural component of maize endosperm and is the main source of concentrated energy. The starch content differed in twenty inbred lines, ranging from 57.67 to 73.29 per cent. Among inbreds, QPM lines reported considerably higher starch content ranged from 68.55-73.29 per cent compared to normal maize inbred lines ranging from 57.67-68.55 per cent. The significantly higher value of TSS content was found in HQPM-1 (12.42%). QPM showed relatively higher values ranging from 8.59-12.42 per cent, and normal maize showed lower values ranging from 4.51-8.43 per cent.

Crude fiber is the fifth largest component in maize grains after carbohydrates, protein, fats and moisture content. The content was slightly higher for QPM ranged from 2.58-2.81 per cent than normal maize lines which ranges from 2.12-2.71 per cent. In the present investigation, marginal difference was observed for ash content among the QPM and normal maize inbred lines. Ash content of QPM lines ranged from 1.43- 1.85 per cent while in case of normal maize the range was 1.22-1.76 per cent. The differences observed among the varieties could be due to genetic factors inherent in the different varieties, environmental factors or agronomic practices with which they were grown.

Correlations between proximate composition parameters

All twenty genotypes of maize inbred lines show a positive correlation between them (Table 3).

Data presents Pearson's correlation coefficients between proximate composition parameters. Moisture content correlated very strongly with TSS (R^2=0.601**), fiber (R^2=0.565**), lysine (R^2=0.588**) and tryptophan (R^2=0.791**) content. A strong positive correlation was exhibited by oil content with tryptophan (R^2=0.586**) content among the crude protein, starch and lysine content. The same trend was observed for crude protein with starch (R^2=0.677**), fiber (R^2=0.604**), lysine (R^2=0.710**) and tryptophan (R^2=0.880**) content.

The phytonutrient components contents were presented in Table 4 for twenty maize inbred lines. Total phenolic content ranged from 147.18 to 173.65 mg/100g of dry weight of maize flour for QPM lines with significantly higher value for HQPM-1 local check whereas normal lines had slightly lower value of phenolic content ranged from 62.16 to 145.18 mg/100g. The antioxidant activity of hydrophilic maize extract was ranged from 196.56-218.52 µg of ascorbic acid/g of dry maize flour for QPM lines with significantly higher value for HQPM-1 while normal lines found to had lower content of 150.84-190.65 µg of ascorbic acid/g.

The carotenoid content was slightly higher for QPM lines which ranged from 0.72-0.77 mg/100g of dry weight of maize flour with significantly higher value for HQPM-1 whereas normal maize showed lower value for carotenoid content of 0.51-0.75 (mg/100g).

DISCUSSION

Maize is a major cereal crop for human nutrition worldwide. With its high content of carbohydrates (72%), fats (4.8%), proteins (10.4%), ash (17%), fiber (2.5%), some of the important vitamins and minerals, maize acquired a well-deserved reputation as a nutriacereal (Farhad et al., 2009). The limitation with maize kernels where it is consumed as a staple food is deficiency or limited content in supplementary foods necessary to upgrade the nutrients ingested in relatively large amounts of maize.

Ullah et al. (2010) reported the moisture value in ten corn genotypes in the range of 9.3-12.7 per cent, which is in close agreement with our results. NRC (1988) reported excessive moisture content for the mature opaque-2 maize, about 2-4 per cent higher than that of normal varieties, that takes prolonged drying time, making it more susceptible to mould infestation. The oil results agree with Sokrab et al. (2012) reported oil content in the range of 2.20–6.00 per cent in corn genotypes. Osei et al. (1999) reported oil content in the range of 4.30 to 5.12 per cent and 4.20 to 4.48 per cent in QPM and normal maize, respectively, which show similarity with our work. QPM genotypes showed slightly higher oil content values than normal maize genotypes, revealing the nutritional importance of QPM genotypes.

The values for protein content fall within the range as reported by Bressani et al. (1990), the authors reported 9.40 and 12.20 per cent protein content in common maize and QPM lines, respectively. Vasal (2005) studied protein-related characteristics of maize grains in QPM lines and reported 8.00-11.00 per cent protein. Further, the starch results are consistent with published work by Sharma et al. (2002). The authors reported starch content in the range from 61.23 to 77.74 per cent in maize cultivars. Ullah et al. (2010) observed that starch content varied from 65.60 to 74.50 per cent, all at par with our results. Znidarcic et al. (2008) reported total soluble sugar in maize cultivars from 3.16 to 10.86 % in sandy soil where as in clay soil, it was ranged from 3.0 to 10.79 % shows agreement with our results. Higher starch and TSS content in QPM make them potentially superior varieties compared to normal maize lines.

Similar range of crude fiber was observed by Jadav and Chavan, (2001) which was 1.5 to 3 per cent. Ullah et al. (2010) reported crude fiber in the range of 0.80-2.32% in maize varieties in Pakistan. Sokrab et al. (2012) reported the ash content ranges from 1.00-1.60 % in maize lines which is in the range of our results.

This study investigated maize inbred lines' carotenoid content and antioxidant properties. The carotenoid content was observed, in good agreement with other authors (Hu & Zu, 2011, & Scott & Eldridge, 2005). The levels of phytonutrients such as carotenoids and polyphenols differ significantly in different corn genotype (Hu & Zu, 2011, Zilic et al., 2012, & Scott & Eldridge, 2005). These results are related with previous studies that pigmented corns have high total phenol content greater than that of the other corns at some maturity stage (Hu & Zu 2011, & Zilic et al., 2012).

Previous studies have demonstrated that polyphenols play a key role against oxidative damage and are the most important contributors to the antioxidant capacity in plant food (Adom & Liu 2002, & Adom et al., 2005). Other authors have demonstrated that a purple corn extract contains various bioactive phenolic compounds that exhibit considerable in vitro antioxidant activity in the isolated mouse organs as the experimental model (Ramos-Escudero et al., 2012).

Table 1: Details of the maize inbred lines used in the study with range of lysine and tryptophan content

Sr. No.	Inbreds	Normal/QPM lines	Lysine content (% of protein)	Tryptophan content (% of protein)
1	CML-490	Normal	3.40	0.57
2	CML-264	Normal	2.47	0.58
3	CM-123	Normal	2.91	0.56
4	CML-269	Normal	**3.58**	0.63
5	CML-292	Normal	3.34	0.59
6	CML-186	Normal	2.90	0.62
7	V-35-1	Normal	3.09	0.64
8	CM-500	Normal	2.92	0.63
9	CML-482	Normal	3.57	0.68
10	CML-307	Normal	3.22	0.63
11	CM-140	Normal	2.80	0.68
12	CM-298	Normal	2.86	**0.69**
13	CML-135	Normal	2.96	0.67
14	CLQ-30	QPM	3.79	0.95
15	CLQ-47	QPM	3.61	0.89
16	I-07-57-5	QPM	**3.90**	0.86
17	I-07-12-1	QPM	3.75	0.88
18	HKI-193	QPM	3.72	0.77
19	HKI-163	QPM	3.85	**0.96**
20	HQPM-1	QPM	**3.91**	**1.02**

Table 2 Proximate composition of twenty maize inbred lines

Sr. No.	Name of Inbred lines	Moisture content (%)	Oil content (%)	Crude Protein (%)	Starch (%)	TSS (%)	Fiber (%)	Total ash (%)
1	CML-490	7.84	4.79	10.4	63.80	5.14	2.55	1.22
2	CML-264	8.71	5.12	9.73	62.54	5.16	2.19	1.53
3	CM-123	8.87	3.29	10.51	57.67	4.51	2.36	1.29
4	CML-269	6.38	**5.18**	11.22	66.58	7.57	2.44	1.72
5	CML-292	9.48	4.12	9.42	65.62	7.72	2.44	1.46
6	CML-186	7.76	4.31	10.88	65.08	7.75	2.12	1.65
7	V-351	8.53	3.08	11.75	64.64	7.57	2.46	1.40
8	CM-500	8.53	2.33	10.43	66.23	7.37	**2.71**	**1.76**
9	CML-482	9.29	4.20	11.61	61.15	6.91	2.21	1.50
10	CML-307	5.70	3.90	11.88	**68.61**	**8.43**	2.49	1.38
11	CM-140	5.13	4.08	10.88	59.66	5.32	2.44	1.42
12	CM-298	**9.64**	4.76	**12.11**	60.87	6.82	2.5	1.71
13	CM-135	6.58	4.24	11.79	66.44	7.32	2.15	1.65
14	CLQ-30	17.27	5.13	12.59	70.72	9.73	2.72	1.43
15	CLQ-47	**14.56**	4.80	12.55	70.92	9.77	2.61	1.51
16	I-07-57-5	10.35	**5.88**	12.84	68.55	8.59	2.81	1.55
17	I-07-12-1	10.67	4.81	12.82	69.85	7.50	**2.79**	1.71
18	HKI-193	8.48	4.88	12.35	**71.90**	10.89	2.58	1.74
19	HKI-163	14.26	4.85	13.23	70.92	**11.25**	2.75	**1.85**
20	HQPM-1	**13.19**	**5.95**	**13.64**	**73.29**	**12.42**	**2.81**	**1.82**
	Mean	9.56	4.49	11.63	66.25	7.79	2.51	1.56
	S. Em.	0.13	0.04	0.12	0.84	0.08	0.06	0.04
	C.D. @0.05	0.37	0.11	0.35	2.39	0.24	0.18	0.10
	C.V. %	2.34	1.52	1.80	2.18	1.87	4.38	3.88

Table 3 Correlation analysis for proximate composition among 20 maize genotypes

Sr. No.	Parameters	Moisture content	Oil content	Crude Protein	Starch	TSS	Fiber	Total ash	Tryptophan	Lysine conten
1	Moisture conte	1								
2	Oil content	0.4	1							
3	Crude Protein	0.556*	0.501*	1						
4	Starch	0.543*	0.465*	**0.677****	1					
5	TSS	**0.601****	0.434	**0.756****	0.894**	1				
6	Fiber	**0.565****	0.299	0.604**	0.629**	0.563*	1			
7	Total ash	0.205	0.271	0.467*	0.498*	0.589*	0.279	1		
8	Tryptophan	**0.791****	**0.586****	0.880**	**0.753****	**0.803***	**0.716***	0.477*	1	
9	Lysine content	**0.588****	0.559*	0.710**	**0.738****	**0.727***	**0.686***	0.27	0.758**	1

Table 4 Phytonutrient components of twenty maize inbred lines

Sr. No.	Inbred lines	Phenol content (mg/100g)	Antioxidant activity (µg of ascorbic acid/g)	Carotenoid content (mg/100g)
IL 1	CML-490	87.55	150.84	0.66
IL 2	CML-264	90.84	166.52	0.70
IL 3	CM-123	103.84	169.85	0.68
IL 4	CML-269	70.48	172.65	0.60
IL 5	CML-292	62.16	155.85	0.51
IL 6	CML-186	80.65	162.54	0.64
IL 7	V-351	115.58	188.45	0.71
IL 8	CM-500	102.46	160.26	0.69
IL 9	CML-482	99.85	155.58	0.65
IL 10	CML-307	121.85	185.58	0.72
IL 11	CM-140	130.46	**190.65**	0.74
IL 12	CM-298	**145.18**	195.65	**0.75**
IL 13	CM-135	120.18	189.84	0.70
IL 14	CLQ-30	155.51	199.65	0.75
IL 15	CLQ-47	147.18	196.56	0.73
IL 16	I-07-57-5	167.18	205.12	0.76
IL 17	I-07-12-1	149.54	198.15	0.72
IL 18	HKI-193	168.41	210.65	**0.77**
IL 19	HKI-163	**173.65**	**218.52**	0.73
IL 20	HQPM-1	**177.84**	**220.51**	**0.77**
	Mean	123.51	184.67	0.69
	S.Em.	0.06	0.04	0.40
	C.D. @0.05	0.18	0.13	1.15
	C.V. %	3.14	1.83	1.14

CONCLUSION

The inbred lines had different proximate composition and antinutrient properties compared to the designated references. Differences in the inbred lines under the study's genetic composition may explain the large variance. The inbred lines studied showed that QPM lines had slightly higher values for proximate and phytonutrient properties than normal lines. Therefore, QPM lines represent the best potential sources of genes for nutritionally better inbred lines. Information about the health-promoting components of local maize inbreds could lead to a better understanding and increased consumption of these, including their use as functional foods.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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Authors contribution:

P. Mankad designed and conducted the experiment and prepared the manuscript with the assistance of N. Patel and J. Talati, who mentored the whole experiment, and Galani Joseph. M. Mankad checked and corrected the manuscript.

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