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Assessment of physical characteristics of quality protein maize (QPM) and common maize

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Abstract

The present study analyzed the physical characteristics of Quality Protein Maize (QPM) and common maize grains. The results revealed the length, width and thickness of QPM grains as 10.7 ± 0.03 , 10.1 ± 0.03 and 5.1 ± 0.01 mm and 9.2 ± 0.03 , 8.1 ± 0.05 and 4.6 ± 0.03 mm, respectively for common maize grains. Seed weight and seed volume of QPM was 37.07 ± 0.06 g/100 grains and 29.96 ± 0.05 ml/100 grains which was significantly higher than that of common maize as 21.53 ± 0.11 g/100 grains and 17.96 ± 0.15 ml/100 grains. The hydration capacity and swelling capacity was significantly higher for QPM i.e. 11.14 ± 0.20 g/100 grains and 19.78 ± 1.05 ml/100 grains. The results of particle size distribution showed the maximum retention of flours on 85 mesh sieve. The study concluded that QPM grains has good physical and thus can be utilized in developing quality food products.

Keywords: Quality protein maize (QPM), common maize, physical characteristics

Introduction

Maize, botanically referred as '*Zea mays*', belongs to the tribe *Maydeae* of the grass family *Poaceae*. The genus *Zea* consists of four species out of which *Zea mays* L. is considered as economically important. In India, it is known by different name like "Maize" in English, "Makka cholan" in Tamil and Malayalam, "Makka" in Hindi, "Chujak" in Manipuri, "Makkejola" in Kannada, "Mako" in Konkani and "Mokka javanalu" in Telugu. Maize is mainly used for 'feed', 'fodder' and 'food'. It is used for developing about 3,500 products. It is used as raw material for making various industrial products such as packaging material, pharmaceuticals, cosmetics, alcoholic beverages, gums, textiles, oil etc (APEDA, 2023) [2]. Maize is referred as poor man's nutraceutical because it has high content of macronutrients i.e. carbohydrates, fat, protein and certain vitamins and minerals.

Biofortification enables development of nutrient-rich crops using different breeding techniques. The strategy of biofortification has been adopted by many countries for developing staple food crops with micronutrients that they originally lack. There are different types of biofortified maize such as Provitamin-A biofortified maize, Zinc biofortified maize low phytate maize, Quality Protein Maize, etc (Gupta *et al.*, 2015) [9].

Quality Protein Maize (QPM) is a biofortified crop which is rich in quality protein containing all essential amino acids in balanced amount. QPM has got special distinction among the cereals due to the presence of four essential amino acids including lysine, tryptophan, isoleucine and leucine which are generally present in imbalance proportion in other cereals particularly common maize (Prasanna *et al.*, 2001) [16]. In QPM, zein content is reduced by 30% which led to increase in concentration of lysine and tryptophan. The concentration of leucine is decreased and thus balanced ratio leucine and isoleucine is attained (Jat *et al.*, 2009) [12]. The present study was carried out to assess the physical characteristics and functional properties of QPM (Quality Protein Maize) and common maize, so that QPM can be incorporated in developing nutritious food products.

Materials and Methods

Procurement of raw material

Quality Protein Maize (QPM) variety Vivek QPM-59 was procured from Vivekananda Parvatiya

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Krishi Anusandhan Sansthan (VPKAS), Almora, Uttarakhand and common maize variety Pant Sankul Makka-3 was procured

from Breeder Seed Production Centre, G.B. Pant University of Agriculture and Technology, Pantnagar (Fig.1).



Fig 1: Quality protein maize and common maize grains

Physical characteristics of grains

Length, width and thickness of QPM and common maize grains were assessed using Vernier calliper having least count of 0.02 mm and then geometric mean, diameter, sphericity and sphericity index were determined using the methods of Mohsenin (1986)^[14]. Surface area and colour of both the grains were determined using the methods of Jain and Bal (1997)^[10] and Oladunmoye *et al.* (2010)^[15], respectively. True density and bulk density of grains were determined according to the method given by (Jha, 1999)^[13] and Asoegwu *et al.* (2006)^[3], respectively. Other physical characteristics including swelling capacity, swelling index, seed weight, seed volume, hydration capacity and hydration index were determined using the method given by Williams *et al.* (1983)^[22].

Statistical analysis

All the experiments were conducted in triplicates and mean and standard deviation (Mean $\pm$ SD) was calculated. Two sample t-test was applied for comparing means with help of WASP-Web Agri Stat Package software developed by Jangam *et al.* (2004)^[11].

Results and Discussion

Physical characteristics of grains

Physical characteristics of grains are indicator of grain quality and yield and influence various operations in processing of grains like grading, sorting, cleaning and milling. Physical characteristics of grains affect its market value and consumer acceptability. The results of physical characteristics of QPM and common maize grains are presented in Table 1(a) and table 1(b). Colour of the maize grains was measured using Munsell colour chart. The colour was recorded as 10YR7/8 which indicates yellow colour for both types of grains. The length, width and thickness of QPM grains were found to be 10.7 ± 0.03 , 10.1 ± 0.03 and 5.1 ± 0.01 mm, respectively, which were higher than the values obtained for common maize grains as 9.2 ± 0.03 , 8.1 ± 0.05 and 4.6 ± 0.03 mm, respectively. A significant ($p \leq 0.05$) difference was seen in length and width of QPM and common maize grain whereas non-significant difference was observed in thickness for the same grains. Semassa *et al.* (2016)^[18] reported length, thickness and width of common maize grain between the range of 7.9-18.1mm, 3.6-8.5 mm and 7.4-15.1mm, respectively. A study conducted by Bala *et al.* (2019)^[4] reported the length, thickness and width of HQPM5 grains as 9.2, 3.8 and 7.8 mm,

respectively.

Geometric mean diameter of grains helps in standardizing the pore dimensions of sieves for separation of grains based on size. In the present study, geometric mean diameter of QPM (8.2 ± 0.01 mm) was found to be significantly ($p \leq 0.05$) higher than common maize (7 ± 0.01 mm). A study conducted by Bala *et al.* (2019)^[4] recorded geometric mean diameter of HQPM 5 as 6.64 mm which is lower than the values of present study.

Sphericity measures the closeness of the shape of grain to that of a sphere. According to Dutta *et al.* (1988)^[8], grains are said to be spherical when sphericity value is more than 0.7. Sphericity determines rolling and sliding property of the grain and helps in designing hopper for milling process (Shah *et al.*, 2015)^[19]. It also affects the degree of milling in a way that the degree of milling will be less if grain is more spherical. The sphericity of both QPM and common maize grain was 0.76 ± 0.01 which means both grains were spherical. Yenge *et al.* (2018)^[23] recorded the sphericity of common grain as 0.65 which is lower than the value found in the present study. The sphericity index of QPM and common maize grain was 76.41 ± 0.88 and $76 \pm 1.30\%$, respectively. The statistical analysis showed that there was non-significant ($p \leq 0.05$) difference in both sphericity and sphericity index of QPM and common maize grains.

Table 1(a): Physical characteristics of QPM and common maize grains

Physical parameters	QPM	Common maize	t-value
Colour	10YR7/8 (Yellow)	10YR7/8 (Yellow)	NA
Length (mm)	10.7 ± 0.03	9.2 ± 0.03	7.46*
Width (mm)	10.1 ± 0.03	8.1 ± 0.05	5.05*
Thickness (mm)	5.1 ± 0.01	4.6 ± 0.03	NS
Geometric mean diameter (mm)	8.2 ± 0.01	7 ± 0.01	13.04*
Sphericity	0.76 ± 0.01	0.76 ± 0.01	NS
Sphericity index (%)	76.41 ± 0.88	76 ± 1.30	NS
Surface area (mm ²)	182 ± 0.05	132 ± 0.03	13.46*

*Significant difference, NS- non significant difference

Surface area of grains influences the rate of heat transfer during heating and drying. It helps in designing heat exchangers and driers (Barnwal *et al.*, 2011)^[5]. In the present study, the surface area of QPM was found to be 182 ± 0.05 mm² which was found to be significantly ($p \leq 0.05$) higher than common maize grain (132 ± 0.03 mm²). Bala *et al.* (2019)^[4] recorded the surface area of common grain as 138.433 mm² which is higher than the value

reported in the present study for common maize as $132 \pm 0.03 \text{ mm}^2$. The variations in findings may be due to the varietal differences.

The seed weight of QPM and common maize grains was 37.07 ± 0.06 and $21.53 \pm 0.11 \text{ g/100 grains}$, respectively. The statistical analysis showed significantly ($p \leq 0.05$) high seed weight of QPM grains as compared to common maize grains. Gupta *et al.* (2009) [9] reported seed weight of Vivek QPM 9 as $22.3 \text{ g/100 grains}$ and Sangeeta and Grewal (2018) [17] reported seed weight of HQPM 1 and HQPM 7 as 27.55 and $28.83 \text{ g/100 grains}$, respectively, which is lower than the value found in the present study. A study conducted by Semassa *et al.* (2016) [18] reported seed weight of common maize ranging from 15.80 to $30.51 \text{ g/100 grains}$, respectively, and seed weight for common maize grains ($21.53 \pm 0.11 \text{ g/100 grains}$) in present study fall in this range.

Table 1(b): Physical characteristics of QPM and common maize grains

Physical parameters	QPM	Common maize	t-value
Seed weight (g/100 grains)	37.07 ± 0.06	21.53 ± 0.11	199.31*
Seed volume (ml/100 grains)	29.96 ± 0.05	17.96 ± 0.15	127.33*
Hydration capacity (g/100 grains)	11.14 ± 0.20	7.17 ± 0.12	28.58*
Hydration index	0.3 ± 0.01	0.3 ± 0.01	NS
Swelling capacity (ml/100 grains)	19.78 ± 1.05	6.56 ± 1.28	13.74*
Swelling index	0.64 ± 0.03	0.33 ± 0.06	7.64*
True density (g/cm^3)	1.23 ± 0	1.19 ± 0	12.47*
Bulk density (g/ml)	0.67 ± 0.01	0.74 ± 0	16.48*

*Significant difference, NS- non significant difference

In the present study, the seed volume of QPM was $29.96 \pm 0.05 \text{ ml/100 grains}$ which was significantly ($p \leq 0.05$) lower than the common maize grain as $17.96 \pm 0.15 \text{ ml/100 grains}$. A study conducted by Shobha *et al.* (2014) [20] recorded seed volume of QPM grains as 38 ml/100 grains .

The chemical composition of grain and thickness of pericarp influences the hydration capacity of grains. Hydration capacity affects organoleptic and cooking qualities of product. The hydration capacity of QPM ($11.14 \pm 0.20 \text{ g/100 grains}$) was significantly ($p \leq 0.05$) higher than common maize grains ($7.17 \pm 0.12 \text{ g/100 grains}$) whereas there was non-significant ($p \leq 0.05$) difference in hydration index of QPM and common maize grains. The hydration index of both QPM and common maize grains was found to be 0.3 ± 0.01 . Sangeeta and Grewal (2018) [17] reported hydration index of HQPM 1 and HQPM 7 as 0.45 and 0.43 , respectively. Higher hydration capacity permits the grain to absorb more amount of water thereby rendering the grains soft (Dobhal and Raghuvanshi, 2018) [7].

The swelling capacity and swelling index of QPM and common maize grains were 19.78 ± 1.05 and $6.56 \pm 1.28 \text{ ml/100 grains}$, and 0.64 ± 0.03 and 0.33 ± 0.06 , respectively. The statistical analysis showed non-significant ($p \leq 0.05$) difference between QPM and common maize grains. Swelling capacity gives an indication of increase in the volume upon absorption of water. It is an important parameter as changes in volume during processing may change the acceptability of the final product (Anuhya and Dobhal, 2024) [1].

The true density of cereal grains is directly linked to endosperm texture, grain condition and milling yield. Grains with high true density are less susceptible to insect infestation and indicates good quality (Sunil *et al.*, 2024) [21]. In the present study, true density of QPM (1.23 g/cm^3) was significantly ($p \leq 0.05$) lower than common maize ($1.19 \pm 0 \text{ g/cm}^3$). A study conducted by Semassa *et al.* (2016) [18] recorded true density of common maize grains in the range of 1.07 to 1.25 g/cm^3 , respectively. Bala *et al.*

(2019) [4] recorded true density of HQPM5 as 1.11 g/cm^3 .

Bulk density indicates the packaging requirement of a product. It also reflects quality of grain and is affected by certain factors like insect infestation, high moisture content and presence of excessive foreign matter. Statistical analysis showed that bulk density of QPM ($0.67 \pm 0.01 \text{ g/ml}$) was significantly ($p \leq 0.05$) lower than common maize ($0.74 \pm 0 \text{ g/ml}$). Bala *et al.* (2019) [4] recorded bulk density of HQPM5 as 0.98 g/ml whereas Sangeeta and Grewal (2018) [17] recorded bulk density of HQPM 1 and HQPM 7 as 0.73 and 0.74 g/ml , respectively. The factor affecting bulk density of grains is the structure of starch polymers. The loose polymer structure results in low bulk density.

Particle size distribution

The particle size distribution of flour influences the quality of the final product. The shape and size distribution of particles have an important influence on certain aspects of product like processing, taste, appearance, texture, overall acceptability and functionality of final product (Bhatt and Gupta, 2015) [6]. The particle size distribution for QPM and common maize flour is shown in Table 2(a) and 2(b).

Table 2(a): Particle size distribution of QPM flour

Sieve size (%)	Percent retained in sieve	Cumulative percent retained in sieve	Percent finer
16 mesh sieve	0.74 ± 0.01	0.74 ± 0.01	99.26 ± 0.01
44 mesh sieve	16.45 ± 0.12	17.19 ± 0.12	82.81 ± 0.12
60 mesh sieve	23.54 ± 0.01	40.73 ± 0.01	59.27 ± 0.01
85 mesh sieve	58.92 ± 0.01	99.65 ± 0.01	0.35 ± 0.01
Base	0.35 ± 0.01	100 ± 0.01	0

In the present study, QPM and common maize flour had minimum flour retention on 16 mesh sieve i.e. 0.74 ± 0.01 and $0.81 \pm 0.01\%$, respectively whereas maximum flour retention on 85 mesh sieve i.e. 58.92 ± 0.01 and $57.02 \pm 0.01\%$, respectively.

Table 2(b): Particle size distribution of common maize flour

Sieve size (%)	Percent retained in sieve	Cumulative percent retained in sieve	Percent finer
16 mesh sieve	0.81 ± 0.01	0.81 ± 0.01	99.19 ± 0.01
44 mesh sieve	17.62 ± 0.01	18.43 ± 0.01	81.57 ± 0.01
60 mesh sieve	24.15 ± 0.02	42.58 ± 0.02	57.42 ± 0.02
85 mesh sieve	57.02 ± 0.01	99.6 ± 0.01	0.4 ± 0.01
Base	0.41 ± 0.01	100 ± 0.01	0

Percent finer is defined as the amount of sample whose particle size is less than the particular sieve size. The percent finer for QPM and common maize flour ranged from 0.35 ± 0.01 to $99.26 \pm 0.01\%$ and 0.4 ± 0.01 to $99.19 \pm 0.01\%$, respectively and it was found to be highest in 16 mesh sieve (%) and lowest in 85 mesh sieve (%).

Conclusion

This study provides valuable insights into the physical characteristics of QPM and common maize grains. The knowledge of physical properties is essential for designing appropriate machinery for processing, transport and storage of grains. The data pertaining to physical properties is essential in determining and maintaining the quality of final product and predicting their behaviour in various food systems. Both QPM and common maize exhibit good physical characteristics which may be helpful in developing quality food products with the inclusion of Quality protein maize.

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