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Inter-relationship among nutritional quality parameters of maize (*Zea mays*) genotypes

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ABSTRACT

The present study was taken up to understand the inter-relationship among various nutritional components of maize (*Zea mays* L.) kernel. For this purpose, 23 elite maize genotypes received from different centres of All India Coordinated Research Projects on Maize during 2009 and 2010 were used. The samples were ground to powder and processed for the estimation of various nutritional quality parameters such as protein quality, starch, oil and carotenoids and the data was correlated to find the interrelationship between these components. The results showed that the protein content exhibited a significant negative correlation with two important essential amino acids such as tryptophan and lysine. An inverse correlation was found between starch and oil indicating that breeding for high oil maize may lead to lower grain yield. A significant positive correlation was observed between oil content and 100-kernel weight postulating that although increase in oil down-regulate the starch content, the total grain yield, however, would remain unaffected. Protein content showed a non-significant negative correlation with 100-kernel weight. A significant positive correlation was noticed between protein and starch. Another important finding of this study is the positive correlation observed between oil and fat soluble total carotenoids. Breeding for high oil, therefore, would have the added advantage of biofortification of maize. The findings will help to develop improved maize having an answer to better nutrition.

Keywords: Carotenoids, Correlation Maize, Nutritional quality oil, Starch

Maize (*Zea mays* L.) is the most widely distributed crop of the world, cultivated in tropics, sub-tropics and temperate regions to almost in all the conditions of irrigated to semi-arid (Saha *et al*. 2010). It is, after wheat and rice, the most important cereal grain (Singh *et al*. 2008), providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and, more recently, fuel thus justifying its literal meaning, maize: "that which sustains life". Approximately seventy countries grow maize including USA, China, Indonesia, Philippines and USSR as the major producer. In India maize occupies a prominent position (Singh 2010) and each part of maize plant is utilized in one or another way and nothing goes waste. Fifty two per cent of maize produced is used as poultry feed, about 24% as food, 11% as livestock feed, 11% in wet milling industry and rest for breweries and seed with 1% each. Besides being the principal source of carbohydrates and energy, maize like other cereals is also the largest single source of protein in the diet of the people for whom it is a staple food. On an average, the normal maize possess around 8–13% protein, 68–73% starch, 2–5% oil, 2–4% sugar with rest of the material being provided by fibre and minerals etc. (Balconi *et al*. 2007). By altering the nutritional profile, researchers have developed numerous types of corn with different uses in the recent past. Some of these include high starch corn, high oil corn, sweet corn and quality protein maize etc. Corn having more than 72% starch is termed as high starch maize and is highly desired by the maize industry, whereas, maize having more than 6% oil is called high oil maize. Similarly corn having sugar content more than 25% in the milking stage is termed sweet corn maize (Chaudhary *et al.* 2011). However, these nutritional components are interrelated and a variation in one may adversely affect the other like high oil maize may have lower quantity of starch (Li *et al.* 2009), whereas the grains of sweet corn maize are usually shriveled due to lesser quantity of starch in its endosperm. Thus keeping in mind the importance of nutritional components of maize the present study was designed to investigate the interrelationship among various quality components of some elite maize genotypes

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received from different maize centers located across India. The outcomes of the study will immensely help the maize breeders in designing breeding strategies for developing nutritionally improved maize genotypes.

MATERIALS AND METHODS

Twenty three elite maize genotypes received from various centers of AICRP on maize during 2009 and 2010 were used for this study. The samples were oven-dried to reduce the moisture level to meet the accuracy of the results. The kernels were ground to powder by using course and then fine grinding and de-fatted by using petroleum ether and finally kept in desiccators for analysis of various nutritional quality parameters. Protein content was determined by Micro-Kjeldahl method of AOAC (1970). In this method the de-fatted samples were digested until the solution becomes colourless. Further distillation and titration was done by using 8 ml sodium hydroxide and 0.02 N HCl. Tryptophan content was estimated by papain hydrolysis method (Villages *et al.* 1971). The optical density was recorded against blank at 545 nm and tryptophan content was calculated by using a standard curve. Lysine content was estimated colorimetrically by method of Tsai *et al*. (1972) by recording optical density at 390 nm and then calculated by using a standard curve. Starch content was determined by the method of Clegg (1956) using anthrone reagent. After extraction of starch with perchloric acid, it is further hydrolyzed (in an acidic medium) into glucose, which forms a green colour compound on reaction with anthrone reagent. The optical density was recorded against blank at 620 nm. Oil content was estimated by the method of AOAC (1970) using solvent extractor system. In this method, extraction of oil was done by using non-polar solvent petroleum ether (40–60°C). The carotenoids and β-carotene were estimated by ether extract spectrophotometrically at a wavelength of 450 nm and then by column chromatography by the method of Rodriguez *et al.* (2004), respectively. The separation of biologically active carotenoid pigments from total carotenoids is based upon adsorbent (column material) having varying affinities for different pigments. Correlation Coefficient analysis and Response Surface analysis was done by using Statistical Analysis Software (SAS 9.2 English) and Scatter plot Matrix was plotted by using SAS Enterprise Guide 4.2 version.

A Pearson Correlation Coefficient |r| among 23 maize varieties was calculated by taking Prob > | r | under (Null Hypothesis) H0: Rho=0 by the formula given below:

$$r = \frac{\Sigma XY - \frac{(\Sigma X)\ (\Sigma Y)}{n}}{\sqrt{\left(\sum X^2 - \frac{(\Sigma X)^2}{n}\right)\left(\sum Y^2 - \frac{(\Sigma Y)^2}{n}\right)}}$$

RESULTS AND DISCUSSIONS

Correlation coefficients among various traits such as protein, tryptophan, lysine, test weight, specific gravity, oil, starch, carotenoids and β-carotene are given in Table 1. Protein content exhibited a significant negative correlation between tryptophan and lysine showing that protein quality may also improve without increase in protein quantity. Tryptophan and lysine are two limiting amino acids in maize. The nutritional quality of maize protein is poor because of the deficiencies of these two main essential amino acids. There exits association of high lysine and tryptophan with *opaque*-2 maize endosperm after Mertz, 1964. Presence of *opaque*-2 gene reduced the synthesis of 22kD alpha-zein and increases the synthesis of non-zein protein fractions, particularly glutelin resulting in increased tryptophan and lysine in endosperm protein (Holding *et al.* 2011, Sofi *et al*. 2009, Gibbon and Larkin 2005). Again with the suppression of zein the total protein might have reduced contributing to the inverse correlation. An inverse correlation was found between starch and oil. Starch is present in the endosperm, whereas, oil is mainly confined to the germ (Boyer and Hannah 2001). An increase in oil, which might have originated from bigger germ size, might have adverse effect on the endosperm volume thus indirectly contributing towards lower starch content. High oil maize is usually associated with higher germ size and lower endosperm compared to normal maize. Therefore, selecting for high oil could adversely affect the starch content. Starch concentration plays an important role in grain yield potential (Boyer and Hannah 2001). It was reported that for high oil strains, as the mean oil concentration increased by 0.03% per generation for five generations, the mean starch concentration decreased by 0.28% per generation (Dudley and Lambart 2004). Contrary to it, a significant positive correlation was observed between oil content and 100-kernel weight. Therefore, it can be inferred that increase in oil could slightly down-regulate the starch content without having significant effect on yield. Duarte *et al.* (2008) also found that oil content was significantly and positively correlated with 100-kernel weight. Protein content showed a non-significant negative correlation with 100-kernel weight. This indicates that protein can be increased through reciprocal recurrent selection procedure without sacrificing the kernel weight or size at least to the degree that reduction in kernel size affects yield. In concluding portion, this observation is in agreement to the studies conducted previously. It was reported that protein and kernel weight were not correlated in random mated population selected in protein content (Okporie and Oselebe 2007).

An important finding of the present study is the significant positive correlation observed between protein and starch content. Both protein and starch are primarily present in the endosperm and a positive correlation between these two components implies that breeding for both starch and protein could be strategized simultaneously. Our results are in dissension with the earlier findings as they brought out a

Tabe 1 Pearson Correation Coefficient | r | vaues among different quaity parameters of maize genotypes

Pearson correation coefficients, N = 23
Prob > |r| under H0: Rho=0

	Protein	Tryptophan	Lysine	Test weight	Specific gravity	Oil	Starch	Carotenoids	β-carotene
Protein	1.00000	–0.61801 0.0017	–0.66440 0.0005	–0.05709 0.7958	0.04871 0.8253	–0.20215 0.3549	0.85305 <.0001	–0.15847 0.4702	0.24792 0.2540
Tryptophan	–0.61801 0.0017	1.00000	0.86959 <.0001	0.19849 0.3639	–0.07396 0.7374	0.24687 0.2561	–0.75779 <.0001	0.12538 0.5687	–0.18549 0.3968
Lysine	–0.66440 0.0005	0.86959 <.0001	1.00000	0.08128 0.7124	–0.10395 0.6369	0.24689 0.2561	–0.80590 <.0001	0.17030 0.4372	–0.02738 0.9013
Test Weight	–0.05709 0.7958	0.19849 0.3639	0.08128 0.7124	1.00000	–0.18741 0.3918	0.29836 0.1667	–0.21412 0.3266	0.20787 0.3412	0.23554 0.2793
Specific gravity	0.04871 0.8253	–0.07396 0.7374	–0.10395 0.6369	–0.18741 0.3918	1.00000	0.33417 0.1191	0.19489 0.3729	0.29238 0.1758	–0.02024 0.9270
Oil	–0.20215 0.3549	0.24687 0.2561	0.24689 0.2561	0.29836 0.1667	0.33417 0.1191	1.00000	–0.33460 0.1186	0.33956 0.1129	0.18265 0.4042
Starch	0.85305 <.0001	–0.75779 <.0001	–0.80590 <.0001	–0.21412 0.3266	0.19489 0.3729	–0.33460 0.1186	1.00000	–0.21752 0.3188	0.02089 0.9246
Carotenoids	–0.15847 0.4702	0.12538 0.5687	0.17030 0.4372	0.20787 0.3412	0.29238 0.1758	0.33956 0.1129	–0.21752 0.3188	1.00000	0.38337 0.0710
β-carotene	0.24792 0.2540	–0.18549 0.3968	–0.02738 0.9013	0.23554 0.2793	–0.02024 0.9270	0.18265 0.4042	0.02089 0.9246	0.38337 0.0710	1.00000

significant negative correlation between protein and starch concentration in maize grains (Dudley *et al.* 2007, Liu *et al.* 2008 and Zhang *et al.* 2008).

Protein content also showed a non-significant negative correlation with oil. Protein is chiefly found in the endosperm, whereas, the oil is mainly present in the germ. In mature maize kernel, endosperm accounts for 80–85% and contributes as much as 80% of total kernel protein. Embryo (germ) accounts for 8–10% of total weight, and may contribute 15–20% of total protein. However, more than 95% of the oil is contributed by the germ. The negative correlation between protein and oil, therefore, might have originated from the relative weight distribution of endosperm and germ in the mature maize kernel. The correlation between seed protein and oil content was studied by some previous workers also. Panthee *et al.* (2005) pointed out that there exists an inverse relationship between seed protein and oil concentration, making it difficult to improve both traits simultaneously. However, Sentayehu (2008) has observed increased concentrations of protein, lysine and other limited amino acids in the high oil maize.

Another important correlation observed is that of oil and carotenoids. Total carotenoids content is positively associated with the oil. The positive correlation between oil and carotenoids implies that selecting maize for high oil could simultaneously help in increasing the carotenoids level and ultimately helping in development of biofortified maize.

Scatter plot matrix analysis

The scatter plot matrix is plotted to show the relationship between two variables by displaying data points on a two dimensional graph (Fig 1). The explanatory variable is plotted on x-axis while the response variable on y-axis. At various places it provides the 'best-fit' resulted from the minimum sum of the squared errors (least squares criterion). The dispersal of data points is inversely related to the correlation between the parameters studied, means higher is the degree of scattering, lesser will be the correlation (whether positive or negative). There exists a falling trend of protein with tryptophan and lysine while rising trend with starch ensuring a significant positive correlation between protein and starch. Starch again continues with a downward trend with lysine as well as tryptophan. These data points are more concentrated on Y-axis for β-carotene indicating poor relation with the explanatory variable. The data points are scattered randomly up to a high extent in specific gravity showing no trend or null correlation with any of other biochemical character. Except oil and β-carotene no other parameter gives outlier in their trend.

Response surface methodology

The explanatory variables (oil and starch) are represented for protein in a three dimensional way as shown in the Fig 2. With the increasing values of protein, Starch is also incurring an upward trend whereas oil in an opposite way. Generally, it was observed by many researchers that protein concentration

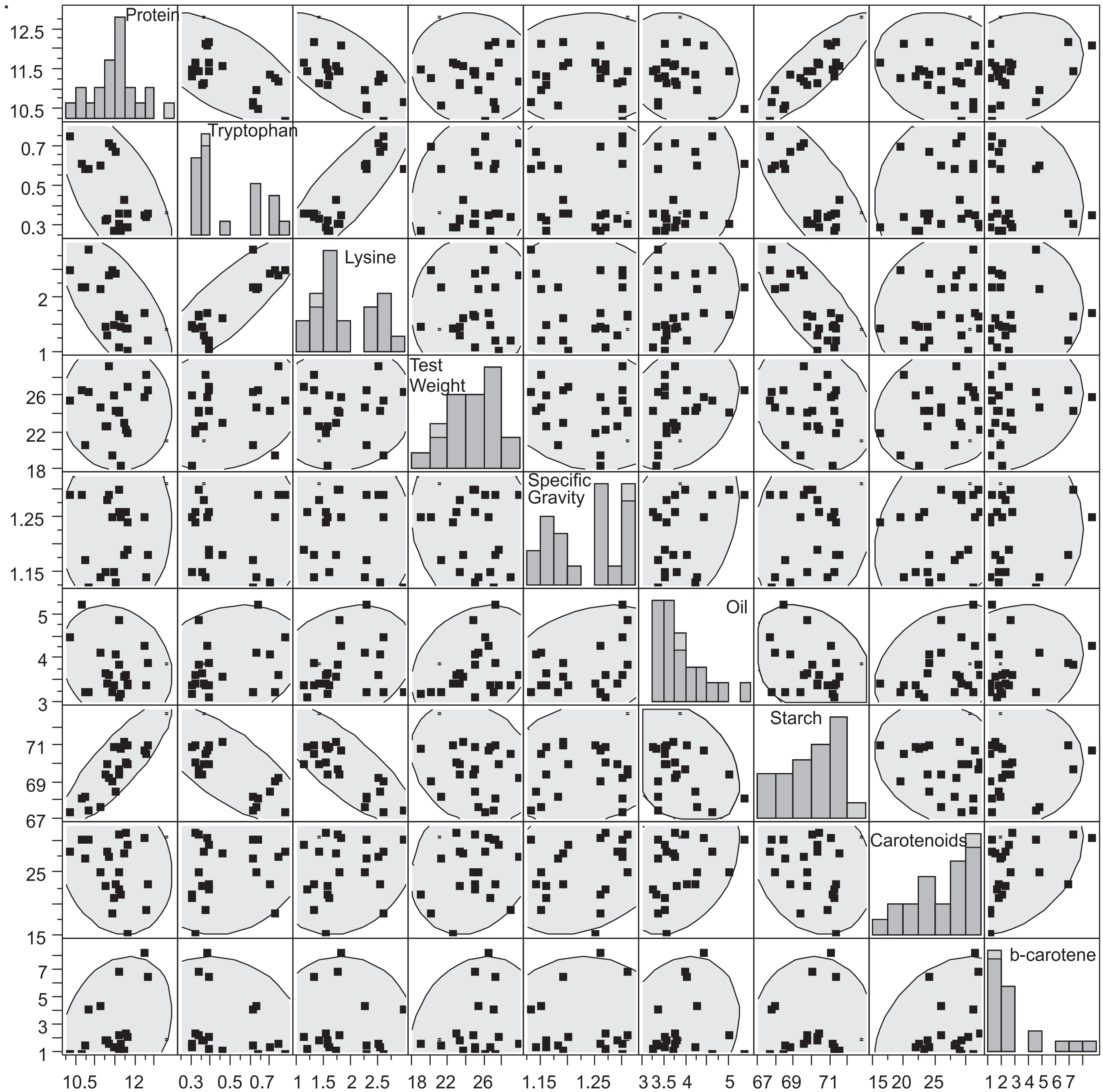

Fig 1 Scatter plot matrix of various quality parameters of maize genotype

is negatively and positively correlated with starch and oil concentration (Dudley *et al.* 2007, Liu *et al.* 2008, Zhang *et al.* 2008)

Finally, we can say that nutritional components in maize are logically interrelated and an alteration in one may adversely affect the other. The development of high oil maize will adversely affect the grain yield as oil and starch are negatively correlated. However, from this study it is firmly concluded that protein and starch are positively correlated and the selection for high protein lines will not affect and, in fact, will add up to the total the grain yield. The outcome of this study can be used by researchers to develop an approach towards future breeding strategies of maize. This might be useful for improved breeding programmes resulting in superior maize genotypes and contribute to nutrition security of the country.

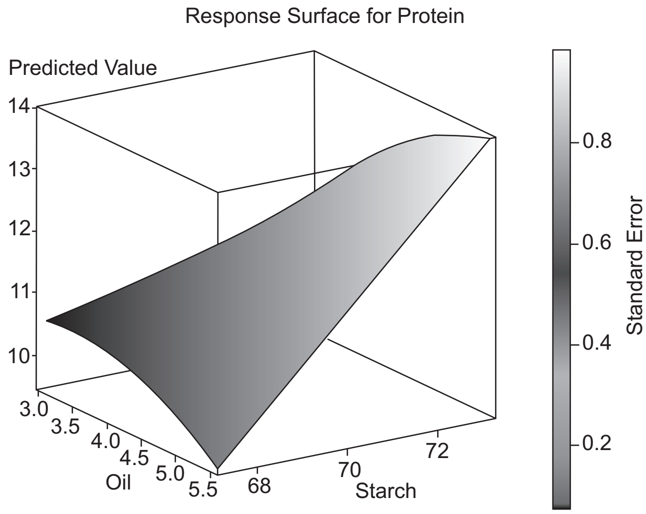

Fig 2 Response surface graph (3-Dimensional) for protein of different maize genotypes

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