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RESEARCH ARTICLE

Rapid depletion of total sugars in stored sweet corn seeds limits shelf life

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Abstract

Sweet corn, a naturally occurring mutant of field corn, is characterized by elevated levels of water-soluble polysaccharides due to the inhibition of sugar-to-starch conversion during seed development. This mutation results in seeds with lower carbohydrate reserves, which pose challenges such as reduced germination, seed vigour, poor field establishment, and limited shelf life. In this study, we investigated the relationship between food reserve levels and seed germination and vigour in sweet corn over a storage period. Seeds from both sweet and field corn, each with 8% moisture content, were stored under three conditions: ambient air, nitrogen, and vacuum. After six months, sweet corn seeds exhibited a 30% decrease in germination under ambient conditions, accompanied by a 73% reduction in total sugars. In contrast, field corn seeds showed a 6% decrease in germination and a 22% reduction in total starch under the same conditions. Notably, seed germination and seedling dry matter production were significantly and positively correlated with food reserve levels in both sweet and field corn across all storage environments. Total sugars were identified as a significant contributor to seed germination in sweet corn ($p < 0.05$), with regression models showing high R^2 values (0.9860 to 0.9998), indicating strong alignment with the observed data. These findings suggest that the depletion of total sugars in sweet corn seeds, driven by respiration and oxidation during storage, plays a critical role in the decline of seed quality and shelf life.

Keywords

field corn; food reserves; seed vigour; shelf life; sweet corn

Introduction

Sweet corn is well known worldwide for its distinct creamy, juicy, sweet taste, crispness, and pleasant flavour. It is a rich source of vitamins A and C, as well as several minerals and it is becoming increasingly popular because it contains zein, a protein used in medicine to produce nutraceuticals (1). Zein is particularly beneficial in nutraceuticals due to its excellent biocompatibility, biodegradability, and ability to encapsulate and deliver bioactive compounds effectively (2). The United States is the leading producer of sweet corn, followed by Japan, Canada, France, and Taiwan. The size of the sweet corn seed market worldwide is currently US$ 820.3 million, and it is predicted to reach US$ 1.19 billion by the end of 2033, increasing at a consistent 3.8% compound annual growth rate (CAGR) https://www.factmr.com/report/399/sweet-corn-seed-market.

Sweet corn is a naturally occurring mutant variety of "starchy" or field corn (3). Genetically, sweet corn differs from field corn because it carries homozygotes for one or more recessive genes involved in the biosynthesis of starch, which regulates the conversion of sugar to starch and ultimately results in ripened seeds with comparatively higher sugar and lower starch content (4). Field corn seeds are composed of 27% carbohydrates, 18% protein, 1% sugar, 6% fat, and 26% fiber, whereas sweet corn seeds consist of 6.8% carbohydrate, 6.2% protein, 13% sugars, 2% fat, and 6.8% fiber (5). Genetically engineered corn can be produced from three varieties: high amylose (40–70% amylose content), waxy (nearly 100% amylopectin starch), and sugary (lower starch but higher sucrose content) (6). Mutation in genes that inhibit the conversion of sugar into starch results in significantly increased levels of water-soluble polysaccharides (WSPs) and twice the sugar content of field corn (7). The main component extracted from the WSP fraction of sweet corn is phytoglycogen, a polysaccharide composed of glucose molecules linked by α-1,4- and α-1,6-glucosidic bonds (8). The accumulation of phytoglycogen results in a creamy texture. However, the rapid conversion of sugar to phytoglycogen after harvest is a major problem affecting seed quality (9).

Sweet corn production is plagued by low seed germination and vigour, poor field establishment, and limited shelf life. Seed germination and vigour are influenced by genotype, which determines intrinsic potential; environmental factors like temperature and moisture; soil-borne diseases that impede growth; and storage duration, which affects seed viability and metabolic integrity (10). Field stand issues are often related to the inherent poor seed vigour and storability of the seeds (11). The poor field stands of sweet corn are associated with insufficient seedling energy reserves due to reduced starch concentrations (12). Similarly, *shrunken2* (*sh2)* hybrids which are super sweet corn varieties that carry the *shrunken2* gene lack sufficient storage carbohydrates for seedling growth compared to normal sweet corn and *sh2* plants are unable to utilize available carbohydrate reserves (13, 14). The typical *sh2* corn seeds are depleted of starch after four days of germination (11). The lower seed weight of *sh2* corn compared with that of normal endosperm corn is the result of low levels of stored carbohydrates (15). The presence of more sugar in the kernel is typically associated with decreased seedling vigour in endosperm mutant seeds. The *sh2* genotype may also be associated with dysfunction of the scutellum or carbohydrate metabolism axis.

Thus, the poor seed quality of sweet corn is largely attributed to its low levels of stored carbohydrates. To address this issue, it is crucial to study the correlation between the depletion of food reserves and the decline in seed germination and vigour during storage. Additionally, there is a need to develop standardized storage technologies to minimize the loss of stored food reserves. Therefore, this study was conducted to investigate changes in kernel food reserve composition and their impact on seed germination during the storage of sweet corn seeds under ambient and modified atmospheric storage conditions. Furthermore, correlation analysis and regression equations were established to understand the impact of kernel food reserves on seed germination and vigour.

Materials and Methods

Sweet corn seeds of the variety *Indum Suruchi* were obtained from Indo-American Hybrid Seeds, Bangalore, Karnataka and field corn seeds of the hybrid *CO H(M) 8* were obtained from the Department of Millets, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu. Seeds of sweet corn and field corn were dried to 8% moisture content and packed in 700-gauge polythene bags to expose the seeds to three storage environments such as ambient air, N_2 (100%) and vacuum (16). The seeds were stored for six months under ambient conditions at the Department of Seed Science and Technology, TNAU, Coimbatore. The stored seeds were subjected to an analysis of seed germination and vigour and food reserve analysis at monthly intervals for all treatments.

Germination tests were conducted with three replicates, each consisting of 100 seeds on germination paper. After that, the seeds were incubated in a germination chamber at 25°C ± 3°C with 1000 lux light for 7 days. The number of germinated seeds was counted daily and reported as the speed of germination. Based on the number of germinated seeds, germination percentage (G%=∑(Gt/Gi), where Gt is the number of germinated seeds on day t), and the Gi total number of seeds sown and the vigour index (VI=G%×SL, where SL is seedling length) were calculated (17, 18). Later, the seedlings were dried in a hot air oven maintained at 85 ± 2°C for 24h, cooled in a desiccator, and weighed (19). The result was expressed as dry matter production (g 10 seedlings^{-1}).

The total starch content in the seeds was determined by following the method mentioned in previous research (20). Native starches in seeds (100 g) of sweet corn and field corn were isolated with toluene alcohol and then extracted with ethanol and hot water. The starch content was then measured spectrophotometrically at 490 nm using the phenolic-sulfuric method. The total sugar content in the seeds was determined using the phenol–sulfuric method (21). Ground seed samples (100 mg) of sweet corn and field corn were sieved using 40µm-mesh sieves, and sugars were extracted with hot 80% ethanol in three repetitions. The combined ethanol extracts were then analyzed spectrophotometrically at 490nm. The reducing sugars in sweet corn seeds were determined by the 3, 5-dinitrosalicylic acid method (22). The total seed protein content was determined using Lowry's method (23) using hot trichloroacetic acid precipitation and alkaline reagent extraction. The extract was then reacted with Folin-Ciocalteu reagent, and the absorbance at 750nm was measured to quantify the protein content in the seeds.

Statistical Analysis

Origin software version 2024b was used to plot the storage data. The Pearson correlation coefficients were calculated and tested for significance at p<0.01 and p<0.05 (24) for the germination with kernel food reserve components. The relationships were then plotted in Origin software (version 2024b). Regression equations between seed germination, vigour and food reserve components were generated in XLSTAT Version 2019.

Results and Discussion

Seeds primarily store reserve foods in the form of carbohydrates, fats and proteins. The availability of food reserves is one of the important factors influencing seed storage potential as revealed by the theory of starvation of meristematic cells (25). Initially, sweet corn seeds contained 180.2mg/g total starch and 256mg/g total sugar, whereas field corn seeds contained 435.2mg/g and 78.1mg/g, respectively (Fig. 1). Thus, food reserves in field corn seeds were dominated by total starch, while sweet corn was rich in total sugar.

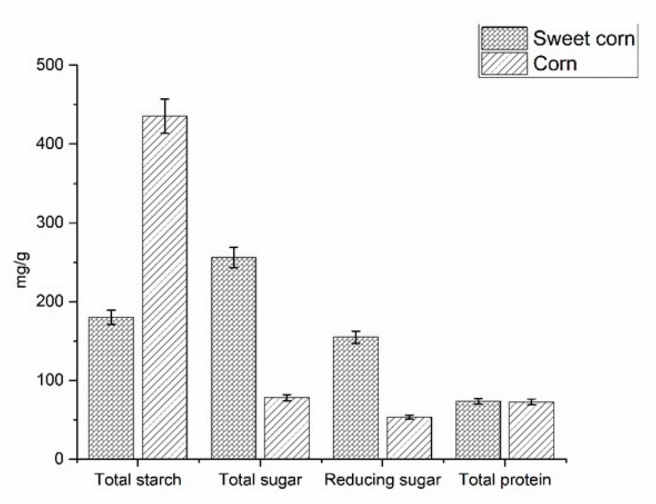

Fig. 1. Food reserves in sweet corn and field corn during initial storage.

Both seed types were stored for six months in three environments such as ambient air, nitrogen and vacuum. Although initial germination of 96% was recorded for both sweet corn and field corn, after 6 months of storage, only 66% germination was recorded for sweet corn, while 90% germination was recorded for field corn under ambient air. The rate of decrease in seed vigour parameters was greater in sweet corn than in field corn (Fig. 2, 3). Sweet corn is generally more susceptible to germination loss compared to field corn due to its unique genetic and physiological characteristics. The sugary (su) endosperm, associated with sweet corn, has been shown to result in reduced germination and shorter seedlings compared to the starchy (Su) endosperm found in field corn (26). Additionally, the presence of the *ae* gene in sweet corn seeds further contributes to decreased seedling emergence and early growth, as it manifests in lower seed vigour (27). The shrunken-2 (*sh2*) genotype, which is common in sweet corn, exacerbates this susceptibility due to the smaller and lighter seeds with a lower endosperm-to-embryo dry weight ratio compared to su or normal plants, making them highly prone to fungal rot during field germination (27, 28). The biochemical composition of sweet corn seeds, characterized by a small endosperm, small embryo, high sugar content, and low starch content, further increases their vulnerability to fungal and soilborne pathogens (29). These factors also promote electrolyte leakage through pericarp fractures, stimulating fungal growth and infection, which further hampers germination (15, 29, 30). In contrast, field corn has a higher starch content and more robust seed structure, providing greater resistance to such challenges. Thus, the distinct seed morphology and biochemical composition of sweet corn make it more prone to germination loss under suboptimal conditions. Over six months of storage, the greatest decrease in food reserves occurred under ambient air conditions, followed by vacuum and nitrogen, for both sweet corn and field corn (Fig. 4, 5). At the same time, the decrease in food reserves over six months of storage was greater in sweet corn than in field corn under all three storage conditions, such as ambient air, vacuum and nitrogen (Fig. 4, 5). Furthermore, in both sweet corn and field corn, the rate of decrease in seed germination and seedling vigour was found to be gradual when stored in nitrogen and vacuum, while it showed a steep decrease when stored in ambient air (Fig. 2, 3).

Food reserves in the endosperm is one of the factors that affect the shelf life of seeds, since seeds require a source of energy for germination after storage (14, 27). The consumption of reserves stored in the endosperm is one of the major causes of the loss of viability of primed rice seeds (31). Pre-consumption of stored reserves might result in a breakdown of the food transport system (31, 32). Respiration is a process that occurs in seeds, by which glucose, along with oxygen molecules, is converted into CO_2 and energy for further utilization in metabolic activities (33). It is one of the important aspects that leads to loss of food reserves such as decrease in protein and non-reducing sugars along with increase in levels of reducing sugars and free fatty acids (34). Ambient oxygen is known to trigger a series of metabolic changes, such as an increase in respiration, consumption of storage reserves, accumulation of ROS and loss of membrane integrity, culminating in seed deterioration (35). Sweet corn and field corn differ significantly in their carbohydrate composition and metabolic activity, influencing their responses to ambient oxygen. Sweet corn has higher concentrations of simple sugars such as sucrose, glucose, and fructose, while field corn primarily stores carbohydrates as starch, which is metabolized more slowly (3). The abundance of simple sugars in sweet corn leads to higher respiration rates, causing faster depletion of energy reserves compared to field corn (11). In sweet corn, rapid sugar depletion also weakens antioxidant defense, exacerbating oxidative damage and membrane integrity loss (36). In contrast, field corn's reliance on starch mobilization slows its metabolic activity, providing greater stability under similar conditions (3).

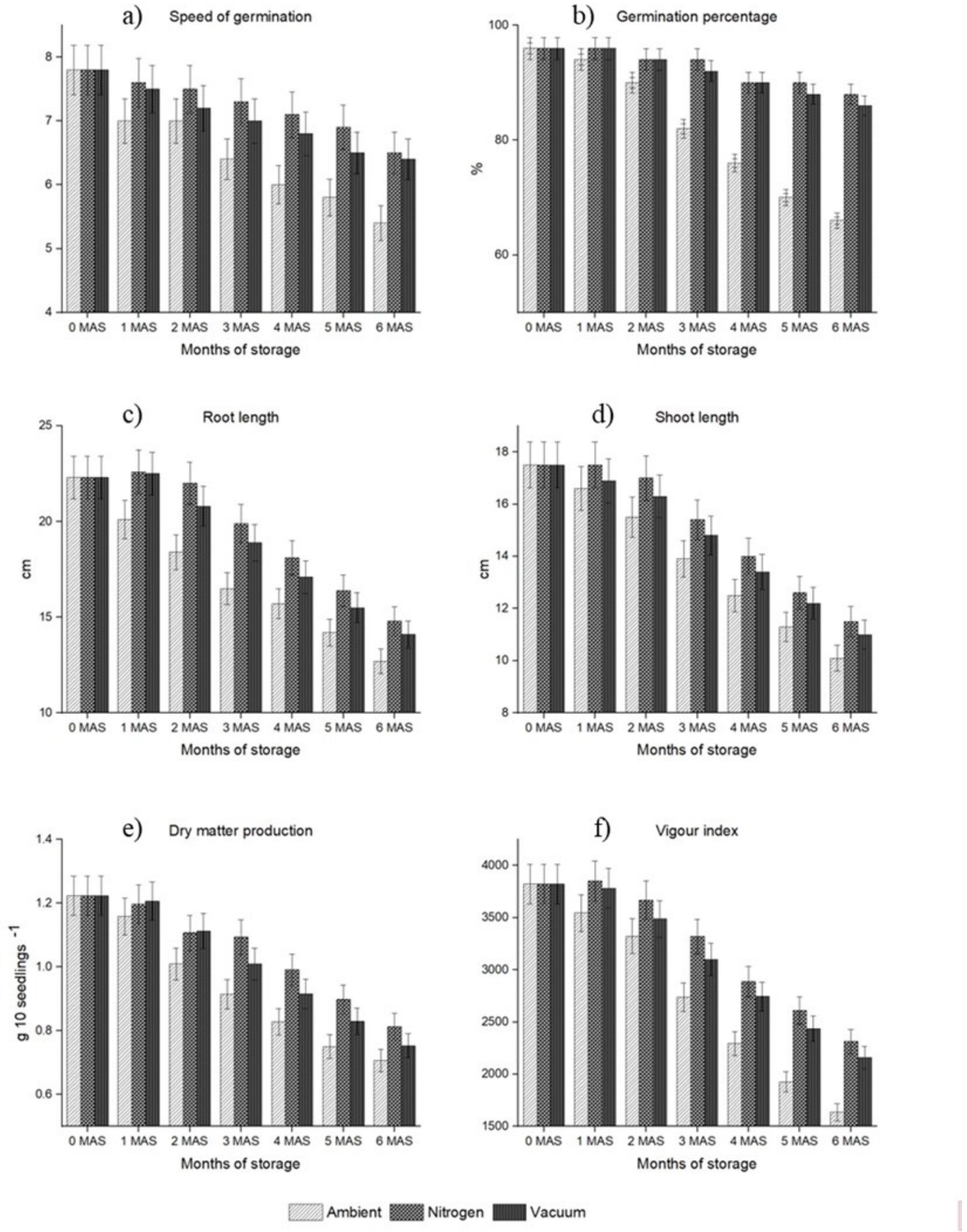

Fig. 2. Effect of modified atmospheric storage on physiological parameter of sweet corn seeds.

High respiration rate can lead to rapid loss of seed reserves of energy and food supplies, especially in the embryo that can result in seeds not being able to germinate (37). Between the total sugars found in sweet corn and total starch stored in field corn, the former is the readily available substrate for respiration; hence, food reserves in sweet corn are more prone to rapid depletion (11). Thus, irrespective of the mechanisms that may be associated with seed deterioration, the loss of seed germination potential of orthodox seeds is known to be significantly influenced by rate of respiration (34). Therefore, reducing oxygen levels in the seed storage environment can lower the rate of respiration and slow the depletion of food reserve, thereby extending seed shelf life.

Seeds also undergo oxidation, which results in faster seed deterioration (38). In particular, oxidative stress might be reduced in oxygen-free storage atmospheres (39, 40). The effect of oxygen on seed deterioration was found to be

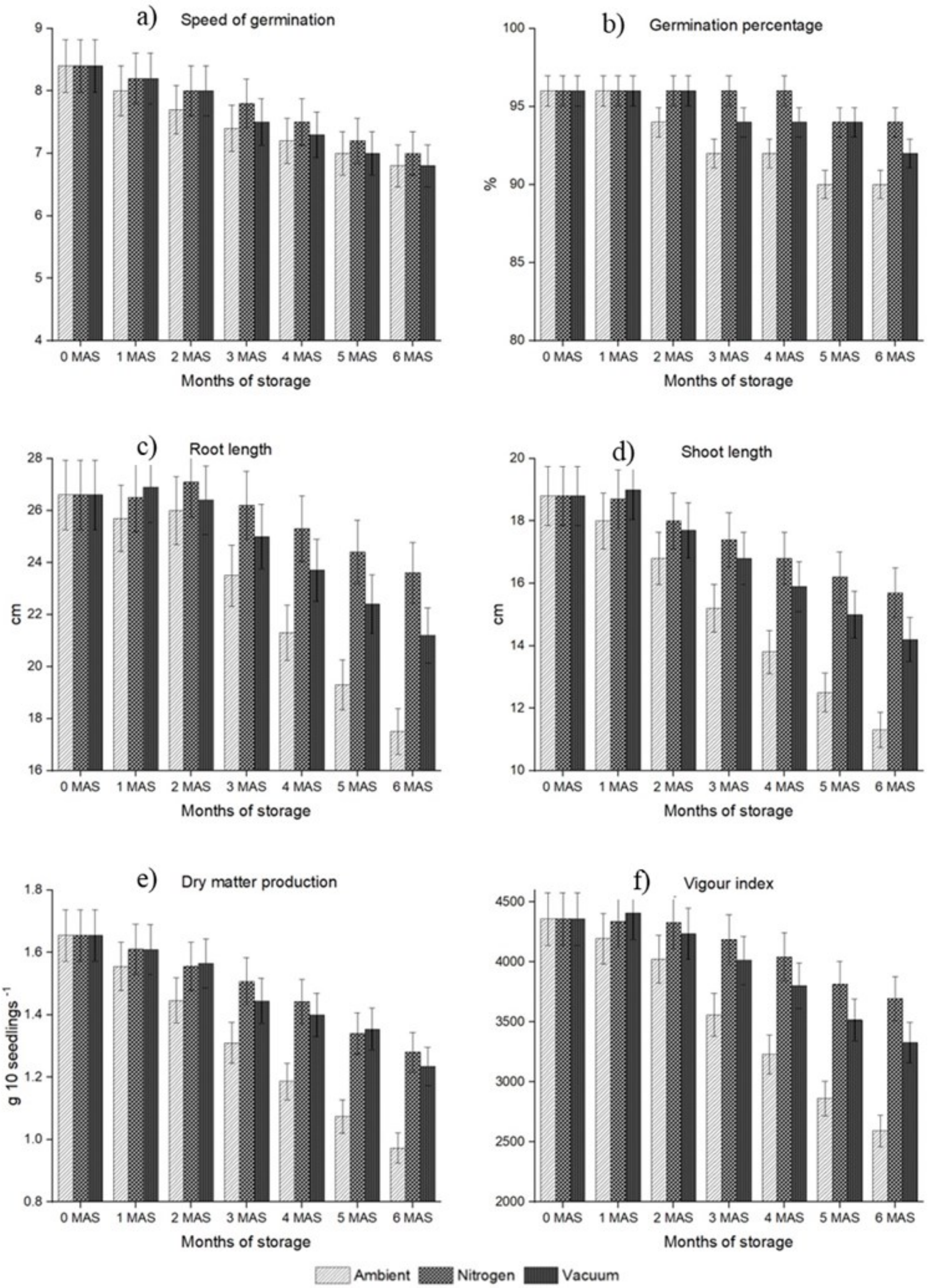

Fig. 3. Effect of modified atmospheric storage on physiological parameter of field corn seeds.

greater when the seeds were stored at a lower moisture content (41). It should be noted that seed deterioration during storage could result in marked changes in the content and activity of enzymes capable of degrading stored reserves (42-44). Low rates of reduction in germination in oxygen-depleted atmospheric environments were observed for chickpeas, soybeans and carioca beans (45-47). A greater than 90% germination capacity was maintained for chickpeas stored under a combination of 80% CO_2 and 20% N_2 for one year (45). Similarly, in another study, soybean plants maintained their germination capacity when stored under CO_2

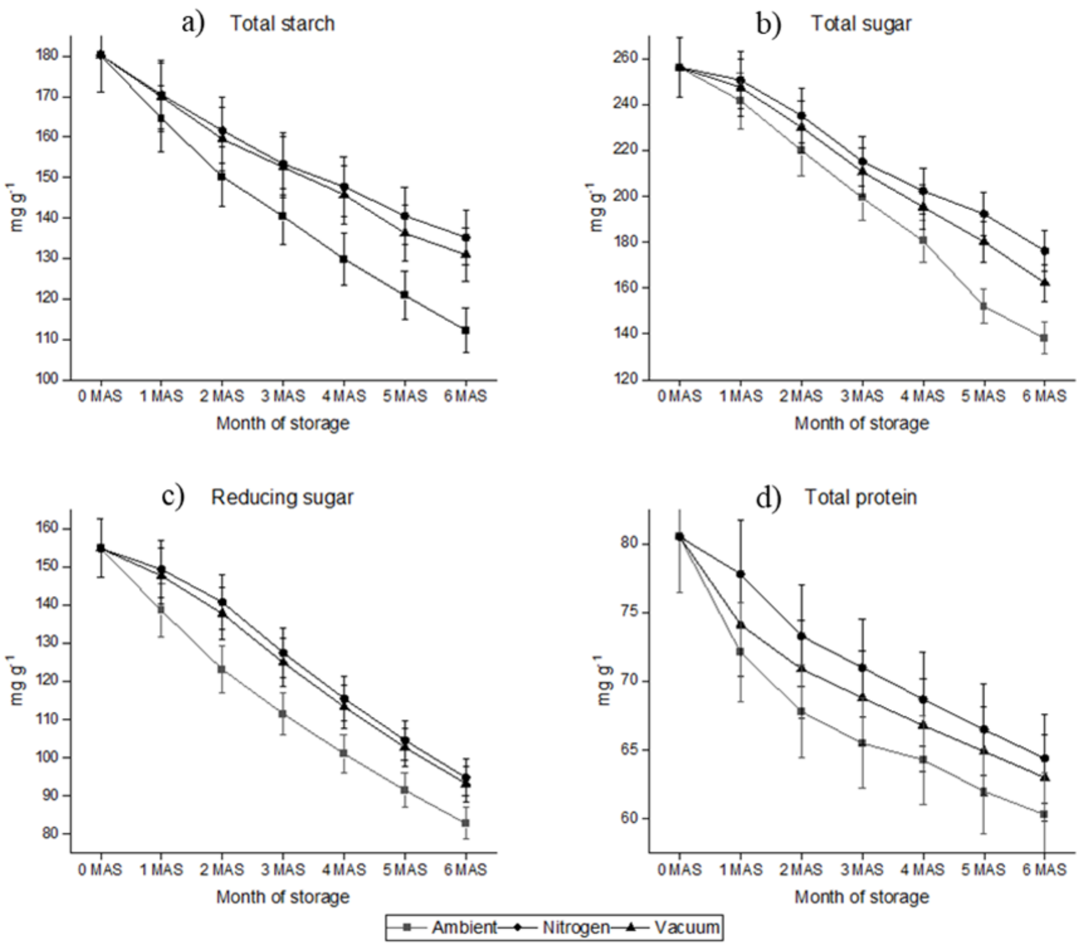

Fig. 4. Effect of modified atmospheric storage on food reserves of sweet corn seeds.

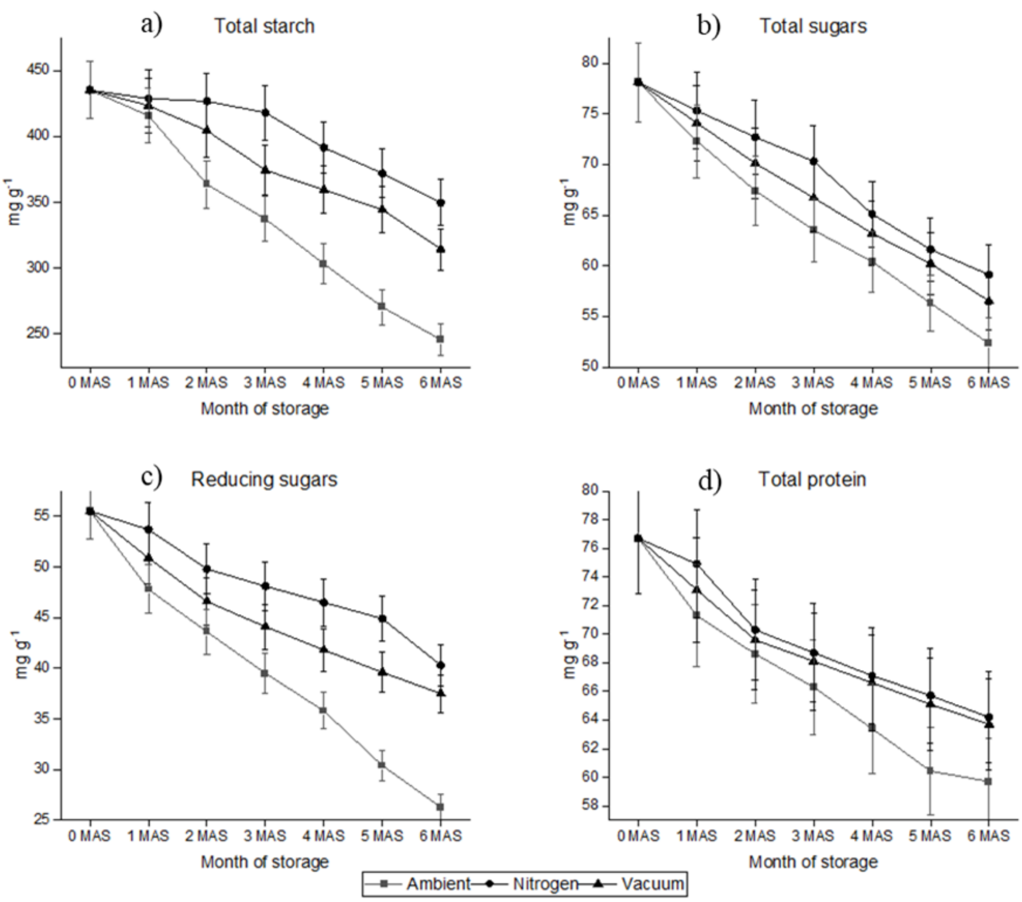

Fig. 5. Effect of modified atmospheric storage on food reserves of field corn seeds.

compared to ambient air (46). Compared with that in an ambient environment, the hydration capacity of carioca beans was maintained when they were stored with N_2 for 360 days (47). A higher concentration of carbon dioxide (60%) and 0% of oxygen in pigeon pea seeds packed with gas enhances seed longevity, resulting in increased seed quality parameters (48). Retaining optimal germination capacity when storing seeds in an oxygen-depleted atmosphere may be associated with the inhibition of oxygen-dependent enzymatic activities, thereby retaining higher levels of seed reserves that is better utilized for seed germination, as observed in soybeans (46).

In sweet corn, germination and seedling dry matter production were significantly and positively associated with all food reserves under nitrogen and vacuum conditions of storage. However, under ambient air conditions, the seed protein content was not correlated with seed germination. In field corn, seed germination and seedling dry matter production were significantly and positively associated with food reserves under all storage conditions (Fig. 6). The data revealed that the availability of storage reserves was strongly associated with seed germination and vigour since it was associated with faster depletion of food reserves, both between the corn types and among the storage environment. Therefore, the decrease in total sugar, the predominant storage reserve in sweet corn seeds, is significantly much greater than the decrease in total starch, the main storage reserve in field corn seeds. The loss of a predominant storage reserve (total sugar) could be one of the most important factors

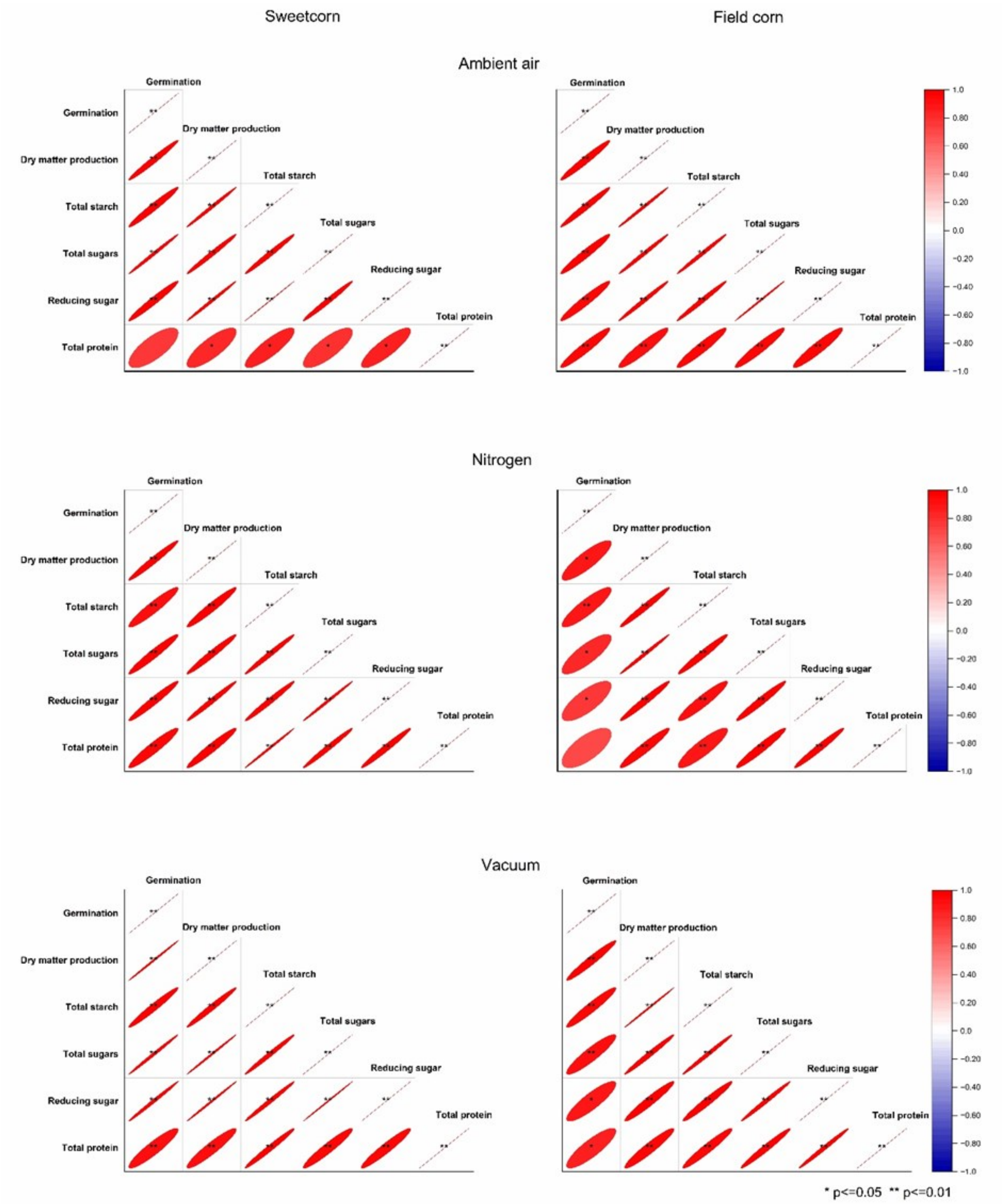

Fig. 6. Correlation matrix for seed germination and food reserves of sweet corn and field corn seeds stored under modified atmospheric storage.

leading to the poor storage potential of sweet corn seeds.

Time series regression equations were used to examine the relationships between seed germination, seedling dry matter production, and kernel food reserves (Table 1, 2). The X_2 (total sugars) under all three storage conditions and X_4 (total protein) under vacuum storage considerably ($p<0.05$) contributed to seed germination in sweet corn. Table 1 shows that X_2 (total sugars) considerably contributed ($p<0.05$) to the production of dry matter in seedlings under nitrogen and vacuum storage condition, while X_4 (total protein) in vacuum storage strongly contributed ($p<0.05$) to the equivalent dry matter production in seedlings under those conditions. In the case of field corn, X_1 (total starch) contributed ($p<0.05$) to germination and seedling dry matter production under all three storage conditions and two storage conditions like nitrogen and vacuum, respectively (Table 2).

The equations with significant X_2 (total sugars) in sweet corn had R^2 values ranging from 0.9860 to 0.9998, suggesting that the equations are highly consistent with the data for sweet corn. Among the nutritive components, total sugar was the main factor affecting the seed germination of sweet corn under all three atmospheric storage conditions. The equations with significant X_1 (total starch) in field corn had R^2 values ranging from 0.9803 to 0.9996, suggesting that the equations are highly consistent with the field corn data. In field corn, total starch had a significant role in influencing ($p<0.05$) germination under all storage conditions. The aforementioned analysis was followed by the development of more straightforward equations using the TSR by removing variables that had negligible impacts on seed germination and seedling dry matter production. The results of the investigation showed that in all three storage atmospheres of sweet corn, total sugars had a substantial ($p<0.05$) impact on both seed

Table 1. Regression equations: Seed vigour vs. kernel food reserves in sweet corn (X_1: Total starch, X_2: Total sugar, X_3: Reducing sugar, X_4: Total protein; Y_1: Germination percentage, Y_2: Seedling dry weight; b_0, b_1, b_2, b_3, b_4: *P* value for intercept and coefficients of X_1, X_2, X_3, and X_4, respectively)

Parameters	Timeseries regression equations	R^2
	Ambient air	
Germination %	$Y_1 = 58.34609 - 0.32817X_1 + 0.291547X_2 + 0.231384X_3 - 0.17933X_4$ ($b_0 = 0.0522$, $b_1 = 0.1584$, $b_2 = 0.0407$, $b_3 = 0.2943$, $b_4 = 0.5858$)	0.9979
Seedling dry weight	$Y_2 = 0.6200591 - 0.00102X_1 + 0.003444X_2 + 0.00288X_3 - 0.00714X_4$ ($b_0 = 0.1842$, $b_1 = 0.7878$, $b_2 = 0.1267$, $b_3 = 0.5155$, $b_4 = 0.3703$)	0.9954
	Nitrogen	
Germination %	$Y_1 = 76.47533 - 0.02096X_1 + 0.096074X_2 - 0.02504X_3 + 0.035366X_4$ ($b_0 = 0.0041$, $b_1 = 0.4285$, $b_2 = 0.0275$, $b_3 = 0.5480$, $b_4 = 0.7110$)	0.9972
Seedling dry weight	$Y_2 = 0.43976 - 0.00182X_1 + 0.001735X_2 + 0.004767X_3 - 0.00105X_4$ ($b_0 = 0.4915$, $b_1 = 0.5079$, $b_2 = 0.0914$, $b_3 = 0.3308$, $b_4 = 0.9168$)	0.9860
	Vacuum	
Germination %	$Y_1 = 43.44124 - 0.05486X_1 - 0.02934X_2 + 0.149504X_3 + 0.637264X_4$ ($b_0 = 0.0066$, $b_1 = 0.0622$, $b_2 = 0.0216$, $b_3 = 0.0130$, $b_4 = 0.0101$)	0.9998
Seedling dry weight	$Y_2 = -0.59773 - 0.00204X_1 + 0.000094X_2 + 0.006767X_3 + 0.015856X_4$ ($b_0 = 0.0677$, $b_1 = 0.4276$, $b_2 = 0.0135$, $b_3 = 0.6876$, $b_4 = 0.0336$)	0.9998

Table 2. Regression equations: Seed vigour vs. kernel food reserves in field corn (X_1: Total starch, X_2: Total sugar, X_3: Reducing sugar, X_4: Total protein; Y_1: Germination percentage, Y_2: Seedling dry weight; b_0, b_1, b_2, b_3, b_4: *P* value for intercept and coefficients of X_1, X_2, X_3, and X_4, respectively)

Parameters	Timeseries regression equations	R^2
	Ambient air	
Germination %	$Y_1 = 81.79741 + 0.04237X_1 + 0.033545X_2 - 0.1117X_3 - 0.01157X_4$ ($b_0 = 0.0001$, $b_1 = 0.0060$, $b_2 = 0.3181$, $b_3 = 0.0771$, $b_4 = 0.6103$)	0.9995
Seedling dry weight	$Y_2 = -0.01639 + 0.000627X_1 + 0.011984X_2 + 0.012102X_3 - 0.00245X_4$ ($b_0 = 0.9497$, $b_1 = 0.4422$, $b_2 = 0.1420$, $b_3 = 0.2069$, $b_4 = 0.5902$)	0.9980
	Nitrogen	
Germination %	$Y_1 = 81.79741 + 0.04237X_1 + 0.033545X_2 - 0.1117X_3 - 0.01157X_4$ ($b_0 = 0.0001$, $b_1 = 0.0060$, $b_2 = 0.3181$, $b_3 = 0.0771$, $b_4 = 0.6103$)	0.9995
Seedling dry weight	$Y_2 = -0.01639 + 0.000627X_1 + 0.011984X_2 + 0.012102X_3 - 0.00245X_4$ ($b_0 = 0.9497$, $b_1 = 0.4422$, $b_2 = 0.1420$, $b_3 = 0.2069$, $b_4 = 0.5902$)	0.9980
	Vacuum	
Germination %	$Y_1 = 90.67311 + 0.089047X_1 - 0.40383X_2 + 0.161154X_3 - 0.14428X_4$ ($b_0 = 0.0289$, $b_1 = 0.0575$, $b_2 = 0.1854$, $b_3 = 0.6374$, $b_4 = 0.7092$)	0.9838
Seedling dry weight	$Y_2 = 0.228723 + 0.004327X_1 - 0.00611X_2 + 0.001848X_3 - 0.00109X_4$ ($b_0 = 0.4406$, $b_1 = 0.0060$, $b_2 = 0.1865$, $b_3 = 0.7182$, $b_4 = 0.8506$)	0.9996

germination and seedling dry matter production (Table 3). On the other hand, under all three storage atmospheres, total starch was revealed to be a significant contributing factor ($p<0.05$) for field corn germination and seedling dry matter production (Table 4). During seed development, total starch was associated with germination percentage and germination index, indicating that seed vigour could be predicted by the total starch content in sweet corn and that vigorous seeds would have greater total starch content (49). Thus, the poor shelf life of sweet corn might be related to a starch-deficient endosperm that cannot sustain early seedling growth through the supply of the required energy (50). Total sugars are essential as the primary energy source during germination, driving metabolic processes essential for seedling establishment (51). Sweet corn seeds, with their inherently high sugar content, experience rapid sugar depletion due to elevated respiration rates (11). Ambient air storage accelerates this process *via* aerobic respiration, while residual enzymatic activity further breaks down stored sugars (52). The high soluble sugar content in sweet corn seeds makes them particularly susceptible to faster depletion compared to other maize types (11). Oxidative stress during storage, especially under air or nitrogen, exacerbates sugar loss by triggering energy-intensive repair mechanisms (53). Additionally, factors like moisture content and temperature significantly influence sugar degradation rates (54). This depletion directly impacts germination and seed vigour, requiring effective storage interventions. Thus, among the nutritive components, total sugar was the main factor affecting seed germination under all three atmospheric storage conditions, *viz.,* ambient air, nitrogen and vacuum. Therefore, the predominant storage reserve of sweet corn, namely, total sugars, might be rapidly depleted due to respiration and oxidation, leading to a shorter shelf life and reduced seed vigour. Furthermore, vacuum storage and low temperatures are effective in reducing sugar loss by minimizing respiration and oxidative stress (55). Antioxidant seed coatings or breeding for genotypes with stable sugar profiles can also enhance

Table 3. Regression equations: Seed vigour vs. Total sugar in sweet corn *(*X_1: total sugar content, Y_1: germination percentage: Y_2: seedling dry weight; b_0, b_1: *P* value for intercept, and X_1, respectively)

Parameters	Time series regression equations	R^2
	Ambient air	
Germination %	$Y_1 = 29.39815 + 0.26534X_1$ ($b_0<0.001$, $b_1<0.001$)	0.9894
Seedling dry weight	$Y_2 = 0.064175 + 0.004424X_1$ ($b_0 = 0.344$, $b_1<0.001$)	0.9770
	Nitrogen	
Germination %	$Y_1 = 70.23923 + 0.1023X_1$ ($b_0<0.001$, $b_1<0.001$)	0.9302
Seedling dry weight	$Y_2 = -0.02909 + 0.004925 X_1$ ($b_0 = 0.793$, $b_1<0.001$)	0.9548
	Vacuum	
Germination %	$Y_1 = 68.15062 + 0.111299 X_1$ ($b_0<0.001$, $b_1<0.001$)	0.9907
Seedling dry weight	$Y_2 = -0.10247 + 0.005241 X_1$ ($b_0 = 0.021$, $b_1<0.001$)	0.9961

Table 4. Regression equations: Seed vigour vs. Total starch in field corn *(*X_1: total starch content, Y_1: germination percentage: Y_2: seedling dry weight; b_0, b_1: *P* value for intercept, and X_1, respectively)

Parameters	Time series regression equations	R^2
	Ambient air	
Germination %	$Y_1 = 80.9846 + 0.03504X_1$ ($b_0<0.001$, $b_1<0.001$)	0.9614
Seedling dry weight	$Y_2 = 0.11932 + 0.003526X_1$ ($b_0 = 0.059$, $b_1<0.001$)	0.9918
	Nitrogen	
Germination %	$Y_1 = 84.80093 + 0.026358X_1$ ($b_0<0.001$, $b_1=0.008$)	0.7795
Seedling dry weight	$Y_2 = -0.18517 + 0.00414 X_1$ ($b_0 = 0.279$, $b_1<0.001$)	0.9600
	Vacuum	
Germination %	$Y_1 = 82.08875 + 0.032896 X_1$ ($b_0<0.001$, $b_1<0.001$)	0.9104
Seedling dry weight	$Y_2 = 0.1610 + 0.003437 X_1$ ($b_0 = 0.003$, $b_1<0.001$)	0.9971

shelf life (53, 56).

Conclusion

The study highlights that total sugars and total starch serve as the predominant storage reserves in sweet corn and field corn seeds, respectively. A strong correlation was established food reserve components and seed quality. Regression equations demonstrated the crucial role of food reserves in seed germination and vigour under ambient and MAP conditions, such as nitrogen and vacuum. Oxygen-free storage environments were shown to significantly reduce the rate of food reserve depletion by limiting aerobic respiration, thereby extending the shelf life of sweet corn seeds. Therefore, the loss of the predominant storage reserve (total sugar) could be the most important factor leading to the poor storage potential of sweetcorn seeds, irrespective of the seed deterioration mechanism that takes place in the seeds. Furthermore, the packing of sweet corn seeds in MAPs with nitrogen or vacuum conditions is highly recommended to preserve seed vigour and prolong shelf life.

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Authors' Contributions

AS performed the experiments, analyzed the data, made the figures and drafted the manuscript. UR designed the study and wrote the protocol. ET, VC, DM, SP and AT reviewed the manuscript. All authors read and approved the final manuscript.

Compliance with Ethical Standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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