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Determination of drying performance of Maize in a single-pass dryer

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Abstract
The purpose of this study is to better understand how agricultural processing facilities might incorporate single-pass dryers (SPDs) to improve the drying, processing, and packing of maize. Given the significance of maize in world agriculture, processing them optimally can boost productivity and cut waste. With the SPD system, drying can be done effectively in just one cycle thanks to its streamlined methodology. The advantages of incorporating an SPD system into current agricultural processing workflows are assessed by our research, which focuses on drying effectiveness, product quality, and operational expenses. The study also looks at how to best handle and package seeds to maximize productivity and preserve quality along the supply chain. This study intends to increase productivity and sustainability in the agricultural industry by offering insights into improving maize processing.

Keywords: Single-pass dryers (SPD), Maize, Agricultural, Drying, Post-harvest, Seed packaging

Introduction
Maize is an important crop for food security and economic stability around the world. Its flexibility makes it a staple diet for billions, but getting it from fields to tables requires extensive processing, with drying being critical. Traditional drying processes frequently confront issues such as extended drying times and quality degradation, necessitating novel solutions. This thesis investigates the use of a single- pass dryer (SPD) to improve maize drying efficiency. The study's goal is to design and optimize an SPD specifically for maize processing using theoretical analysis, and experimental validation. By addressing these goals, the thesis hopes to promote maize processing technology, provide long-term solutions to improve efficiency, reduce post-harvest losses, and help global food security efforts. Maize, also called corn, is a type of grain that grows on tall grass-like plants. The seeds of maize are what we eat. They come in different colors like yellow and white. People eat it as a vegetable, or they grind it into flour to make bread, tortillas, and other foods. Animals like cows and chickens also eat maize. Besides food, maize is used to make things like biofuels, starch, and even some kinds of plastic. Maize is grown in many countries because it can grow in different kinds of weather and soil. It's an important crop because it provides food for people and animals, as well as materials for many different. From Fig. 1, Maize seeds, also known as corn seeds, are the reproductive units of the maize plant. They are the small, oval-shaped structures found within the kernels of the maize ear. The scientific name of maize is *Zea mays*.

It belongs to the Poaceae family, commonly known as the grass family. Maize seeds are vital for the propagation of the maize plant and play a crucial role in agriculture. Maize seeds contain all the genetic material necessary to grow into a new maize plant. When planted in soil under suitable conditions, maize seeds germinate and develop into maize plants. These plants produce ears of maize, each containing numerous kernels, which in turn house the seeds for the next generation. Maize seeds are also a valuable food source for humans and animals. They can be ground into flour to make various food products such as bread, tortillas, and porridge. Single-pass dehuller, often referred to as a dryer, plays a critical role in maize processing by removing the outer layers of maize kernels in one efficient operation. These layers typically include the bran (pericarp), germ, and the tip cap, which are not required in many end-products like maize meal, flour, or grits. The primary function of the dryer is to streamline the dehulling process, reducing the need for multiple machines or repeated handling, which can be both time-consuming and costly.

Fig 1: Life Cycle of Maize.

Maize processing plays a vital role in food security, economic development, and industrial production across many regions, particularly in Africa, Asia, and Latin America. The quality of processed maize products such as flour, meal, and grits depends heavily on the preliminary cleaning and dehulling stages. Traditional methods of dehulling maize often involve multiple passes and labor-intensive procedures, which can result in significant grain loss and inconsistent product quality. In response to these challenges, the single-pass dehuller, or dryer, has emerged as a highly effective solution.

This machine simplifies the dehulling process by removing the bran, germ, and tip cap from maize kernels in one continuous operation. By streamlining this step, single-pass dryers not only save time and labor but also improve the overall efficiency of maize milling. Their use contributes to better end-product consistency, longer shelf life, and higher milling yields, making them essential in both small- and large-scale maize processing industries. Moreover, with a growing emphasis on food safety, sustainability, and cost-effective production, single-pass dehullers have become indispensable tools in modern grain processing systems.

Single-pass dryers are particularly beneficial in regions where maize is a dietary staple and milling operations must meet both high volume and quality standards. These machines are designed to handle varying kernel sizes and moisture levels, ensuring uniform dehulling regardless of the condition of the raw maize. Their adaptability makes them suitable for diverse settings. The drying process was conducted at a specific temperature with a specific airflow rate. Initially, the temperature of the first 2 days (48 hours) is 38℃ in this duration the air will flow upwards and then next 2 days or up to get the desired moisture level the temperature will be maintained at 40℃, here the air will flow downwards. Whenever the desired moisture level occurs then the drying process will be stopped and it will allow further post-processing like shelling, seed treatment and packaging, *etc*. And first two days of the drying process would be done by up air direction later uniform distribution of air to remove moisture content uniformly from the grains. If the moisture content of the seeds is less than 15% then it will be considered as trim. AFurthermore, the efficiency of single-pass dehullers supports value addition across the maize value chain. By producing cleaner, more refined kernels in a single operation, these machines enhance the quality of maize products for both domestic consumption and export markets. In DOIng so, they contribute to increased profitability for processors, improved nutrition for consumers, and more sustainable use of agricultural resources.

Drying characteristics of maize cob

Barrozo *et al.*, (2014) [3] studied seed drying in fixed bed dryers and moving bed dryers, beginning with harvesting, seeds are usually subjected to a series of processes which include drying for immediate or future use. Seed quality can be influenced by several factors during drying. This article presents a review of the seed air-drying process, including mathematical models based on differential equations derived from mass and energy balances for seeds and air in fixed and moving bed dryers. The article concludes with an overview of several potential drying technologies that can be applied to seeds. Fashina *et al.*, (2013) were designed parameters for a small- scale batch in-bin maize dryer, when marketed in its green state, early-season maize, which is harvested with a high moisture content, has storage issues and low profitability. The purpose of creating a batch-in-bin maize grain dryer was to reduce grain losses and boost farmer profit margins. For dryer design, characteristics like bulk density and moisture content were established. With a 100-kg batch size, the dryer is suitable for both commercial and experimental use in farms and labs. It makes it possible to evaluate drying rates, examine how drying parameters affect the quality of maize, and experiment with various drying setups.

Ivan *et al.*, (2013**)** evaluated about process of Drying rate of grain maize, after being harvested at 30-34% moisture, maize must dry to 1-15% to be stored. Temperature, ambient conditions, and maize characteristics all affect drying time. This study looks at the rates of moisture loss and drying of grain maize from different producers and presents the findings in graphical and tabular form. All ten maize samples (twice) attained ≤14% moisture after 30 minutes, with six of them reaching this level in 20 minutes. Initial moisture and moisture loss rates are correlated. In post-harvest treatment, maize drying is essential, particularly for wet crops. Modern dryers use less energy while maintaining the quality of dried corn. Kabiru *et al.*, (2023**)** developed different types of drying techniques for different types of grains, For the production of high-quality grain products, such as flour and beverages, grain drying is essential. Consumer acceptability is impacted by the process, which involves heat and mass transfer between the grain and its surroundings. Numerous drying technologies have been developed, including vacuum, infrared, microwave, and fluidized bed dryers. Through the introduction of treatments like ultrasound and the combination of technologies like microwave, researchers have improved drying efficiency. The necessity of optimizing drying procedures for high-quality grain products is highlighted by this review, which looks at drying conditions, energy usage, and costs related to lowering grain moisture content for safe processing and storage.

Physical properties of maize cobs

Andre *et al.*, (2020) the evaluation of the physiological quality of maize seeds kept in high-temperature, high-humidity environments with different packings. A cold test was used in a 4 x 4 factorial design to assess moisture content, germination, and vigor. After 45 days, the results showed that the moisture content had reached 13.62%, which resulted inreduced vigor because of increased respiration from the storage temperature. ANOVA and regression analysis, along with Tukey tests, were used to identify significant differences. Results show that maintaining seed viability and vigor requires appropriate storage conditions, which may have an impact on agricultural productivity. Chattah *et al.*, (2014) [5] studied the effect of packing materials during ten months of storage, the study looked at the effects of various packing materials (metal bins, earthen bins, plastic bags, cloth bags, and gunny bags) and grain moisture levels (10% and 16%) on the quality of wheat grain. Quality parameters were tracked, such as the presence of insect pests, the weight of 1000 grains, the amount of protein, and the amount of starch. Regardless of the initial moisture content, the usage of gunny, fabric, and plastic bags resulted in decreased grain weight, protein, and starch contents, as well as increased insect- pest infestation over time. On the other hand, wheat grain kept in metal and clay bins, especially when it was 10% damp, showed superior quality through storage, suggesting that a lower initial moisture content led to a slower rate of quality degradation.

Manje *et al*., (2017) With an emphasis on genetic quality concerns, this technical handbook explores quality assurance and quality control (QA/QC) procedures in maize breeding and seed manufacturing. High-quality seed should not be mixed with impure seed; QC finds and fixes production-chain faults. It highlights the benefits of combining morphology-based testing with molecular marker-based analysis, which allows for trait-specific analysis, parent- offspring testing, and genetic purity and identity assessment. The handbook also describes how to evaluate nutritional features based on the kernel, such as provitamin A and QPM, which improve the overall quality of seed in maize breeding and seed production operations.

Monir *et al*., (2016) evaluated packaging using morpho-anatomical features to evaluate the purity of maize hybrid seed in Uganda. In 13 areas, 120 samples of four common hybrids were gathered. At NaCRRI, Namulonge, evaluation was conducted utilizing an alpha lattice design. Within hybrids as well as between seed sources, significant differences ($P < 0.05$) were discovered. Other than that, Longe 9H did not differ much from the others. A principal component analysis showed that hybrids had a variety of traits. The different levels of contamination show that more quality control is required to increase farmer production.

Neerja *et al*., (2019) examined about grain quality of rice, the quality of rice grains affects milling, appearance, cooking, and nutrition and is therefore critical to market value and consumer approval. Breeding methods require an understanding of the genetic foundation of quality attributes. This chapter examines the progress made in enhancing grain quality characteristics and combining them with high yields in the face of resource scarcity.

Methodology

The Materials required for the Maize drying process to dry the seeds to get the desired moisture content & materials required for processing and packing are discussed below. the results pertaining to engineering properties of maize, design and development of different components of maize dehusker cum sheller, testing and evaluation of maize dehusker cum sheller were presented and analysed. The economics of maize dehusker cum sheller were also presented in this chapter. The results are presented under the following headings.

Engineering properties of maize

The various engineering properties of maize were determined using the standard procedures as explained in section 3.2 of chapter 3. The physical properties of maize grains were evaluated at a moisture content of 10-14% (w. b.). The dimensions and other related parameters for all the selected four maize varieties are given in Table 4.3. The measured mean length of dehusked cob was minimum (175.05 mm) in case of S-605 variety and maximum (182.2 mm) in case of KU-89 variety. The measured mean length from all the varieties of maize was found to be 179.28 mm with deviation of 3.12 mm. The diameter of un-dehusked maize cob was maximum (55 mm) in case of S- 605 variety followed by KU-89 (53 mm), S-609 variety (50.5 mm) while it was minimum in S607 variety (49.5 mm). The mean value found to be 52.0 mm with 2.4 8 mm deviation. Among all the four varieties, the maximum stalk length was observed in S- 605 (33.7 mm) and a minimum of 29.6 mm was observed in S-609 variety whereas mean value was found to be 31.32 mm with deviation of 1.90 mm. The mean linear dimensions involved length, breadth and thickness of maize grains. The maximum ear length of 11.9 mm was obtained in S-605 variety while it was minimum (10.2 mm) in S-607 The maximum value was found in S-605 (9.8 mm) and minimum (8 mm) in KU- 89 variety. The measured mean thickness was found to be 5.81 mm with deviation of 1.67 The number of grain lines in cob ranged from 13 to 16.03 for all the four varieties of maize with a calculated mean of 14.95. Among the four varieties, the number of grains in one line of cob was maximum in KU-89 (40.63) while it was minimum (35.2) in S-607 and the measured mean value was calculated to be 38.18 with deviation of 2.27. The measured maximum diameter of cob without grains was noted in (24.11 mm) KU-89 variety and it was found minimum (20.5 mm) in S-607 variety. The maximum diameter of cob without grains was found to be varied from

25.09 to 29.37 mm for all the four varieties of the maize. The maximum diameter (29.37 mm) of the cob was found for KU-89 variety and a minimum diameter (25.09 mm) was found in S-607. The calculated maximum length of the shelled maize cob of 160.9 mm was noticed in case of KU-89 and minimum length of 140.68 mm for S-609 variety. The mean value was noticed to be 149.52

Physical Properties

The roundness of maize grain varied from 0.24 to 0.32 for all the four varieties of the maize. The maximum roundness of the maize grain was found for S- 609 variety (0.32) and the minimum (0.24) for S-607. The Arithmetic mean diameter of the maize grains was found to be in the range of 7.61 to8.55 mm with a mean value of 8.15 mm. The maximum arithmetic mean diameter was recorded in KU-89 variety while it was minimum (7.61 mm) in S-609 variety. The measured geometric mean diameter of all the varieties of maize grains was found in the range of 7.1 to 8.05 mm with calculated mean value of 7.68 mm. The sphericity of maize grain was found maximum (0.73) in case of S-605 variety followed by KU-89 (0.72), S-609 variety (0.69) while it was found minimum (0.65) in S-607 variety.

The maximum surface area of 229.67 mm^2 was observed in CP 818 variety while it was noticed minimum (181.04 mm^2) in S-609 variety. The mean bulk density of all the maize varieties was found to be 0.74 g cm^{-3}. The maximum (0.78 g cm^{-3}) bulk density was found in S-607 and the minimum bulk density (0.69 g cm^{-3}) was recorded in S-605 of 0.98 to1.11 g cm^{-3} and with mean value of 1.03 g cm^{-3}. The maximum tested weight of the maize grain was found in the case of S- 607 (317.60 g) and observed minimum of 224.13 g for S-605 variety. The measured mean value of the four varieties was noticed to be 276.58g with deviation of 46.96g.

Shelling

This machine consists of an Auger fixed at two ends of the Sheller Casing with the help of heavy-duty bearings. The SS cage is provided over Auger to separate Seeds. The Augur helps to pull the cobs inside, convey them forward, separate the Seeds, and push the empty cobs out of the machine. Shelling is accomplished by the beating and throwing action of the fins attached to the Auger. Modified Design of the Auger and the steel cage keep the Germination of seed unharmed. (Seed does not get ruptured or damaged). The shanks (empty cob) are thrown/pushed out by the force exerted by end plates through the specially designed flapper outlet. The Shelled Seeds are collected at the bottom for further process of cleaning and grading by using sieves. If the maize cobs have more moisture content than the required level for shelling then it leads to reduced efficiency of shelling. Fig. 2 represents series of unit operations involved in handling the maize cops.

Fig 2: Maize Cop Handelling

The machine capacity depends upon the consistency in the operations, the product type, and the cob moisture content and feed rate (*i.e.* more feed rate less capacity, and low quality). Therefore, the user only is the best judge to decide and can correlate the capacity to the amount of specific product being fed to the machine. It is necessary to do the changeover after the completion of the shelling of one Hybrid variety.

Dryer key performance indicators (KPI)

A corn processing plant typically uses several key performance indicators (KPI) to measure the effectiveness, efficiency, and overall effectiveness of various processes and operations. Here are some key performance indicators that are often used in corn processing plants. Fig. 3 shows the complete procedure of processing of maize.

Admixture of Hybrids

The target value of the admixture of Hybrid is **0**.

Average Intake Moisture (%)

The target value of Average intake moisture is 28 – 32%. If the moisture is greater than 32% then the Load has more milky cobs. The milky cobs have a lower germination rate.

$$\text{Average Intake Moisture} = \frac{\text{Sum of average sample moisture taken in a day}}{\text{Number of samples taken in a day}}$$

Truck unloading time (in hr)

The target value of truck unloading time is 0.3 hours. The truck unloading time will vary when the load comes with bags.

$$\text{Truck Unloading Time} = \frac{\text{Total number of trucks unloading time in a day}}{\text{Number of trucks in a day}}$$

2.3.4 Sorting accuracy (%)

The target value of sorting accuracy is 100%. The sorting accuracy lies between 98 – 99% then the flag of the load is GF.

$$\text{Truck Unloading Time} = \frac{\text{Total weight of cobs} - \text{Sum of weight (off-type + male + fungus)}}{100}$$

Up Air Temperature

The target value of up air temperature is 38℃ ± 1.

$$\text{Up Air Temperature} = \frac{\text{Sum of average temperature of up air in a day}}{\text{Number of average temperature readings of up air in a day}}$$

Down Air Temperature
The target value of up air temperature is 40°C ± 1.

$$\text{Down Air Temperature} = \frac{\text{Sum of average temperature of down air in a day}}{\text{Number of average temperature readings of down air in a day}}$$

Bin utilization
The target value of bin utilization is 100%

$$\text{Bin Utilisation} = \frac{\text{Total number of bins used}}{\text{Total number of bins}}$$

Dryer utilization
The target value of bin utilization is 100%

$$\text{Dryer Utilisation} = \frac{\text{Total number of bins} - (\text{Number of empty bins} + \text{Number of cut-off bins})}{\text{Total number of bins}}$$

Shell seed moisture (%)
The target value of shelled seed moisture is <11.5%

$$\text{Shelling Moisture} = \frac{\text{Sum of average shelled sample moisture taken in a day}}{\text{Number of samples taken in a day}}$$

Change over at intake (hr)
The target value of shelled seed moiture is <11.5%

$$\text{Change Over at Intake} = \frac{\text{Time taken to change over the hybrid in a day}}{\text{Total number of change overs in a day}}$$

After completion of the shelling process, the shelled grains will be conveyed to the bin by using a belt conveyor and bucket elevator. We will dispatch the maize into the jumbo bags from that bin which has a capacity of 2.5 tons. And we note the Flag, Moisture content, Lot number, Hybrid, and capacity on that jumbo bag. This jumbo bag will be transported to storage in a warehouse for further processing.

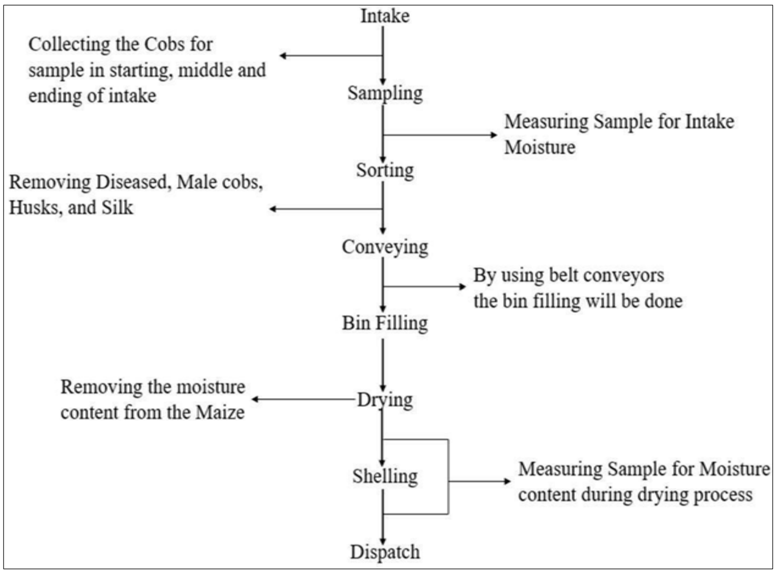

Fig 3: Maize Drying by using Single Pass Dryer.

Results and Discussion
The results and discussion section presents a comprehensive evaluation of the use of a Single-Pass Dryer (SPD) in maize processing at Prasad Seeds Private Limited. The study investigates the operational performance and drying efficiency of the SPD system through theoretical analysis and practical experimentation. Key aspects examined include drying kinetics, moisture reduction efficiency, energy utilization, and the influence of the drying process on maize quality parameters. Furthermore, optimization strategies for improving dryer performance and processing efficiency were analysed. The findings demonstrate the potential of SPD technology to enhance maize drying operations, improve post-harvest handling practices, and contribute to sustainable agricultural production and global food security initiatives.

Drying characteristics of maize cob
The operational evaluation of the Single-Pass Dryer (SPD) used for maize drying at Prasad Seeds Private Limited demonstrated significant effectiveness in reducing grain moisture content to safe storage levels. The study revealed that the initial down-air moisture content of maize ranged from 19.8% to 20.6%, which was successfully reduced to a final cut-off moisture level of 10.3%–10.5%. This indicates that the SPD system maintained consistent drying performance across different batches. The total drying duration varied between 114.35 and 131 hours depending on the initial moisture content and operational conditions. Batch 2 required the highest drying time (131 h) due to comparatively higher initial moisture content (20.6%), whereas Batch 3 exhibited the shortest drying duration (114.35 h) with an initial moisture content of 19.8%. These findings suggest a direct relationship between initial grain moisture and total drying time. From Table 1, the results further indicate that continuous blower and burner operation ensured uniform airflow and heat distribution within the dryer, contributing to efficient moisture removal and minimization of grain quality deterioration. The SPD system effectively achieved the recommended safe moisture range for maize seed storage while maintaining operational stability. Overall, the study confirms that the Single-Pass Dryer is a reliable and efficient technology for maize drying operations, offering improved drying efficiency, reduced post-harvest losses, and enhanced seed quality management in commercial seed processing industries.

Table 1: Dryer characteristics of maize

S. No	Blower On Date/Time	Burner On Date/Time	Down Air Date/Time	Down Air Moisture%	Cut Off Date/ Time	Cut Off Moisture, %	Total No. of Drying Hours
1	13/3/25 (12:50)	13/3/25 (15:20)	15/3/25 (18:30)	20.3	17/3/25 (18:50)	10.3	123
2	13/3/25 (15:40)	13/3/25 (19:00)	15/3/254 (18:40)	20.6	17/3/25 (6:10)	10.5	131
3	17/3/25 (16:45)	17/3/25 (18:25)	19/3/25 (8:10)	19.8	21/3/25 (15:00)	10.5	114.35

Dryer Key Performance Indicators (KPI)

The operational assessment of the maize drying and processing system at Prasad Seeds Private Limited demonstrated that the processing parameters were maintained within the prescribed operational standards, indicating efficient dryer performance and effective process management as mentioned in Table 2.

Table 2: Dryer Key Performance Indicators (KPI)

S. No	Parameter	Target Value	Observation / Formula	Calculated Value	Remarks
1	Admixture of Hybrids	0	—	0	No hybrid admixture observed
2	Average Intake Moisture (%)	28–32%	(30 + 30.1 + 30.2) / 3	30.1%	Within acceptable range
3	Truck Unloading Time (hr)	1.5 hr	18 / 15	1.2 hr	Lower unloading time achieved
4	Sorting Accuracy (%)	100%	((100) − (0 + 1 + 1)) / 100	98%	Load flagged as GF
5	Up Air Temperature (℃)	38 ± 1 ℃	(37 + 38 + 39) / 3	38 ℃	Meets target value
6	Down Air Temperature (℃)	40 ± 1 ℃	(40.1 + 40.2 + 40) / 3	40.1 ℃	Within standard range
7	Bin Utilization (%)	100%	26 / 26	100%	Full bin utilization achieved
8	Dryer Utilization (%)	75%	((26) − (2 + 4)) / 26	76%	Slightly above target
9	Shelled Seed Moisture (%)	< 11.5%	((10.6 + 10.5 + 10.9 + 10.5 + 10.5 + 10.5) − (2 + 4)) / 6	10.58%	Safe moisture level maintained
10	Changeover at Intake (hr)	0.45 hr	180/4	0.45 hr	Achieved target value

The study showed that the average intake moisture content of maize cobs was 30.1%, which falls within the recommended range of 28–32%. This indicates that the raw material received for drying was suitable for processing and free from excessive immature or milky cobs, which are generally associated with poor germination performance. Furthermore, the admixture of hybrids was recorded as zero, confirming high genetic purity and proper segregation during handling and intake operations. Truck unloading operations were completed within 1.2 hours, which is lower than the target unloading time of 1.5 hours. This reflects efficient material handling and reduced waiting time during intake operations. Similarly, the changeover time at intake was maintained at 0.45 hours, meeting the prescribed target and indicating effective operational coordination. The sorting process achieved an accuracy of 98%, which is close to the ideal target of 100%. The minor reduction in sorting accuracy was attributed to the presence of small quantities of off-type, male, and fungus-affected cobs. However, the achieved value still indicates a highly efficient sorting system capable of maintaining seed quality standards.

Temperature management within the dryer was found to be highly stable. The average up-air temperature was maintained at 38 ℃, while the down-air temperature averaged 40.1 ℃, both within the recommended operating limits. Proper temperature regulation contributed to efficient moisture removal without causing thermal damage to the seeds. The bin utilization efficiency was recorded at 100%, indicating optimum use of available storage and drying capacity. Dryer utilization was observed to be 76%, slightly exceeding the target value of 75%, which reflects effective operational planning and improved equipment productivity. The final shelled seed moisture content was reduced to 10.58%, which is below the maximum permissible limit of 11.5% for safe storage. This confirms that the drying system effectively reduced moisture to levels suitable for maintaining seed viability, minimizing fungal growth, and reducing post-harvest losses. Overall, the findings demonstrate that the drying and processing operations were conducted efficiently, with most parameters meeting or exceeding the target values. The results confirm the suitability of the Single-Pass Dryer system for commercial maize seed processing, ensuring improved drying efficiency, seed quality preservation, and enhanced post-harvest management practices.

Table 3: Physical properties of maize cobs.

Particulars		Average values of varieties				SD	Mean
Name of the varieties		S-607	S-609	S-605	Ku-89		
Length of un de-husked cob, mm		180.9	179	175.05	182.2	3.12	179.28
Diameter of un- dehusked cob		49.5	50.5	55	53	2.48	52
Stalk length, mm		30.0	29.6	33.7	32	`1.90	31.32
Weight of un- dehusked cob, g		205.7	221.9	194.8	225	14.7	211.85
Linear	l	10.2	11	11.9	10.5	0.74	10.9
dimensions	b	8.10	8	9.8	8	0.88	8.475
of maize grains	t	4.39	4.5	6.5	7.85	1.67	5.81
No. of grain lines in Cobs		13	14.9	16.03	15.9	1.40	14.95
No. of grains in one line of cob		35.2	38	38.9	40.63	2.27	38.18

The Table 3 compares the physical characteristics of four maize varieties-S-607, S-609, S-605, and Ku-89-across several key attributes, including cob dimensions, weight, grain lines, and shelled cob length. The length of the undehusked cob ranges from 175.05 mm for S-605 to 182.2 mm for Ku-89, with an average of 179.28 mm, suggesting Ku-89 produces the longest cobs. The diameter of the undehusked cob shows a similar trend, with S-605 having the largest diameter (55 mm) and S-607 the smallest (49.5 mm), indicating S-605's cobs are bulkier in size. When it comes to stalk length, S-605 has the longest stalk (33.7 mm), while S-609 has the shortest (29.6 mm), which might affect plant height and strength. In terms of weight, Ku-89 has the heaviest undehusked cob (225 g), while S-605 has the lightest (194.8 g), highlighting Ku-89's more robust cob. The linear dimensions of maize grains-length, width, and thickness-show that S-605 grains are the largest, with a length of 11.9 mm, a width of 9.8 mm, and a thickness of 6.5 mm, while Ku-89 grains are the thickest at 7.85 mm. The number of grain lines ranges from 13 (S-607) to 16.03 (S-605), with S-605 having the most, which could lead to a higher overall grain yield. Additionally, the number of grains per line is highest in Ku-89 (40.63 grains), indicating its potential for greater grain production compared to the other varieties. The diameter of the cob without grains shows that Ku-89 has the largest maximum diameter (29.37 mm), while S-607 has the smallest. Finally, the average length of the shelled cob is longest in Ku-89 (160.9 mm), suggesting that after dehusking, it maintains a larger cob size compared to the others. Overall, Ku-89 stands out for its large cob size and high number of grains per line, while S-605 offers the largest grains and the highest number of grain lines, making both varieties potentially more productive depending on the specific needs for grain size or yield.

In conclusion, the comparison of these four Maizes varieties-S-607, S-609, S-605, and Ku-89-reveals distinct strengths in different areas. Ku-89 stands out for its larger cobs, both in length and diameter, and its high grain yield potential, as it has the largest number of grains per line and the heaviest undehusked cob. This variety is likely to perform well when larger cobs and higher overall productivity are desired. S-605, on the other hand, excels in grain size, with the largest grains and the most grain lines, making it a strong candidate for higher grain yield in terms of grain number and size. Although it has the lightest cob, the size of its individual grains and the number of lines suggest good productivity. S-607 has smaller cobs and grains compared to the other varieties, but its compact size could still make it suitable for specific environments or markets that require smaller grains. S-609 falls in between, with moderate cob size and grain number, offering a balanced option but lacking the standout features of the other varieties in terms of size and yield.

Overall, the choice of variety depends on the specific goals of the maize production-whether prioritizing larger cobs (Ku-89), higher grain size (S-605), or a balance between the two (S-609, S-607). Each variety has its unique advantages, making them suitable for different agricultural needs and growing conditions.

Table 4: Physical properties of Maize Grains

Properties	Average values of varieties				SD	Mean
	S- 607	S-609	S- 605	KU 89		
Roundness	0.24	0.32	0.30	0.28	0.03	0.28
Arithmetic mean diameter, mm	7.96	7.61	8.48	8.55	0.45	8.15
Geometric mean diameter, mm	7.64	7.10	8.04	8.00	0.43	7.69
Sphericity	0.64	0.68	0.73	0.71	0.04	0.69
Surface area, mm2	198.89	182.04	226.06	229.67	22.71	209.17
Bulk density, g cm-3	0.78	0.77	0.73	0.69	0.04	0.74
True density, g cm-3	1.11	1.04	0.98	0.99	0.06	1.03
Test weight, g	317.60	314.83	224.13	249.77	46.96	276.58
Grain straw ratio	3.16	2.88	3.85	3.29	0.41	3.30

The Table 4 presents a detailed comparison of the physical properties of four grain varieties-S-60, S-609, K, and U 89-across various parameters that influence their quality and performance.

Roundness measures how spherical the grains are, with S-609 exhibiting the highest roundness (0.32), indicating it is the most spherical, while S-60 is the least round (0.24). arithmetic mean diameter shows that K grains are the largest on average (8.55 mm), followed closely by S-60 (7.96 mm), whereas S- 609 has the smallest grains (7.61 mm). Geometric mean diameter follows a similar trend, with K and S-60 having the largest grains and S-609 the smallest. Sphericity is another key property, and S-609, with a value of 0.73, is the most spherical, whereas S-60 is the least spherical (0.64), suggesting it has a more irregular shape. Surface area correlates with grain size, with K having the largest. Surface area (229.67 mm²) and S-609 the smallest (182.04 mm²). Bulk density and true density offer insights into the compactness and solidity of the grains; S- 60 has the highest bulk density (0.78 g/cm³) and true density (1.11 g/cm³), indicating it is the densest and most solid. test weight, which is an indicator of grain quality, also favors S-60, with the highest weight per unit volume (317.60 g), while K has the lowest (224.13 g), suggesting that S-60 may be of better quality. Finally, grain-straw ratio reflects the productivity of the grain; K has the highest ratio (3.85), meaning it produces more grain relative to straw, making it the most efficient, whereas S-609 has the lowest ratio (2.88). Overall, S-60 stands out for its higher density and test weight, while K excels in grain yield efficiency. These properties can guide decisions about which grain variety to choose based on desired characteristics such as size, shape, quality, and yield.

Conclusion
In conclusion, the present study highlighted the significant differences among the four maize varieties—S-607, S-609, S-605, and Ku-89—with respect to their physical characteristics, cob dimensions, grain properties, and yield potential. Among all the varieties, Ku-89 exhibited superior performance due to its larger undehusked cob length and diameter, higher number of grains per line, heavier cob weight, and longer shelled cob length. These characteristics indicate its strong potential for higher productivity and better overall yield. S-605, although having lighter cobs, demonstrated desirable grain-related properties such as larger grain size and a higher number of grain lines, making it suitable for improved grain production. S-609 showed balanced and moderate characteristics in most parameters, suggesting its adaptability and stable performance, whereas S-607 recorded comparatively smaller cobs and fewer grains per line, indicating lower productivity among the tested varieties.

The study also focused on evaluating the drying characteristics of maize cobs using a single-pass dryer (SPD) under different drying temperatures. The experiments revealed that drying temperature significantly influences the drying rate, moisture removal efficiency, and total drying time. Higher drying temperatures resulted in faster moisture reduction and shorter drying periods; however, excessive temperatures may lead to quality deterioration, emphasizing the need for proper temperature optimization during drying operations. Various mathematical drying models were applied to study the drying behavior and identify suitable conditions for efficient drying performance.

In addition, important physical properties such as moisture content, bulk density, porosity, cob size, and grain characteristics were analyzed to better understand their effect on drying efficiency and handling properties. These parameters were found to play a vital role in the design, operation, and optimization of drying systems. The study further demonstrated that the incorporation of a single-pass dryer can improve post-harvest processing efficiency, reduce drying time, maintain product quality, and support sustainable agricultural practices. Overall, the findings of this research provide valuable information for improving maize drying techniques, optimizing processing conditions, and enhancing storage and post-harvest management practices. The study also opens opportunities for future research on advanced drying technologies, automation systems, and efficient seed handling methods to further improve productivity, quality preservation, and sustainability in the agricultural sector.

List of Symbols & Abbreviations
Et al.: And others
Etc.: Etcetera
%: Percentage
kg: Kilogram
SPD: Single Pass Dryer
,: Comma
°C: Degree Celsius
°F: Fahrenheit
±: Plus-minus
^: Exponent
*******:** Multiplication
hr: Hour
m/s: Meter per second
t/hr: Tonne per hour
QC: Quality Control
kg/cm²: Kilogram per centimeter square
i.e.,: That is
<: Less than
KPI: Key Performance Indicator
mm: Millimeter
ml: Milliliter
g/kg: Gram per kilogram
RPM: Revolutions per minute
MRP: Maximum Retail Price
GOT: Grow Out Test
TZ: Tetrazolium Test
GK: Ganga Kaveri
No.: Number

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