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# Development and Evaluation of Baby Corn Grader

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**Abstract**

The power-operated size grading machine for baby corn was designed, fabricated and tested. The grader consists of a feeder, grading unit, collection unit and power transmission system. Two gear motors of 0.5hp are used to operate the grader. The machine grades the baby corn into five grades: 10-12mm, 12-14mm, 14-16mm, 16-18mm & >18mm. The grader was operated at four speeds – 0.7m/min, 1.1m/min, 1.5m/min and 1.9m/min. The performance of the machine was evaluated in terms of its grading efficiency and grader capacity. The max and min overall grading efficiency recorded were 84.9% and 68.8% at the roller speed of 0.7 and 1.9 m/min respectively. The input and output capacity of the grader varied from 63 to 154 kg/h and 241 to 714kg/h respectively under different grader speeds.

**Keywords:** Zea Mays L., Grading, Parallel Roller, Grading Efficiency, Tapered/ Cylindrical Vegetable

## 1. Introduction

Baby corn is a milky tender cob consumed as such as a natural food cum vegetable. It is a low-calorie vegetable which is rich in fibre content. One baby corn can be compared with an egg in terms of minerals. It is delicious, sweet and easy to consume because of its tenderness and sweetness with nutritive value addition. It can be used as a vegetable in daily culinary preparations and for preparing delicacies for special occasions. It occupies an important place in the food processing industry of India. Demand for baby corn as a health food has been increasing (Kaur *et al*, 2022) [7]. It is free from the residual effect of pesticides because it is wrapped tightly with husk and well protected from diseases and pest attacks. Thailand and China are the world leaders in baby corn production. In India, baby corn is being cultivated in Meghalaya, Western Uttar Pradesh, Haryana, Maharashtra, Karnataka and Andhra Pradesh. It is becoming popular in domestic and foreign markets and has enormous processing and export potential.

India exports most of its baby corn to the UK, UAE, Netherlands and Germany and is the largest exporter of baby corn in the world. The top three exporters of baby corn are India, with 49,648 shipments contributing 70% market share followed by Thailand with 5,471 (8% market share) and Vietnam at the 3rd place with 4,959 shipments (7% market share) as fresh, chilled, preserved by vinegar or acetic acid (Anon., 2024). There are three types of baby corn products available in the world market namely fresh baby corn, canned and frozen. Market demand for fresh baby corn is always higher than the canned baby corn. India exported 37802 shipments of fresh baby corn alone to UK, Netherlands and Ireland. Inconsistency in the sizes of baby corn affects both local and export markets. The most suitable cob size is 1.0-1.5 cm. They are graded as large size (11-13 cm long and 1.4-1.5 cm dia), medium size (7-11 cm long and 1.2-1.4 cm dia) and small size (4-7 cm long and 1.0-1.2 cm dia). The optimum size for market and cannery industries is 4.5-10 cm long and 7-17 mm diameter of dehusked cobs. As per CODEX standard for baby corn the length for size-A is 5.0-7.0 cm, B is 7.0-9.0 cm. and C is 9.0-12.0 cm. The size of baby corn varies with the variety also. For all sizes, the minimum width should not be less than 1.0 cm and the maximum width not more than 2.0 cm as per CODEX standard 188-1993 (Jayant & Patil, 2014).

Babycorn grading is one of the important primary unit operations and involves the inspection, assessment and sorting regarding quality, freshness, legal conformity and market value. The benefits of grading include a higher market price for graded goods and the development of greater confidence between buyers and farmers. It improves marketing efficiency by allowing the purchase and sale of goods without the need of manual selection. For the effective marketing of baby corn proper grading facilities are required. In India, most grading is done manually which involves trained operators, who consider several grading factors according to their physical quality. It is costly and grading operations are affected due to a shortage of labour in peak season, so farmers are looking forward to having an appropriate agricultural produce grading machine to alleviate the labour shortage, save time and improve graded product quality.

Grading baby corn based on size and shape is important for marketing uniform high-quality produce and to get suitable returns (Mamoria & Joshi 1982; Krishnamurthy & Rao 2001). In India, there is no machine available for baby corn grading. It is done manually and the industry requires a lot of labour for grading baby corn. Mechanization is of utmost importance as the labour costs are increasing for grading this commercial crop.

For vegetables with cylindrical or tapered profiles *viz.,* carrots, parsnips, sweet potato and cucumber parallel rollers grading system, divergent rollers grading system and multiple belt adjustable V-size grading system are there (Londhe *et al*., 2013; Kheto *et al*., 2023) [9, 8]. Among these, parallel rollers grader is most suitable due to less mechanical injury and higher separation efficiency. However, optimum roller speed, slope and clearance between the rollers decide the optimum grading efficiency (Brantley *et al*., 1975) [4]. In this study, we attempted to develop a parallel roller grader that is suitable for handling and grading baby corn based on girth.

## 2. Materials and Methods

### Development of baby corn grader

A parallel rollers grader suitable for tapered/cylindrical produce was developed using physical properties of baby corn such as maximum & minimum diameter, length, bulk density and angle of repose.

The grader consists of a hopper, main frame assembly, grading assembly, collection assembly and prime mover. The capacity of the feed hopper is 50kg per batch. The main frame assembly consists of the main frame, supports and cross-stay bars (Fig 1).

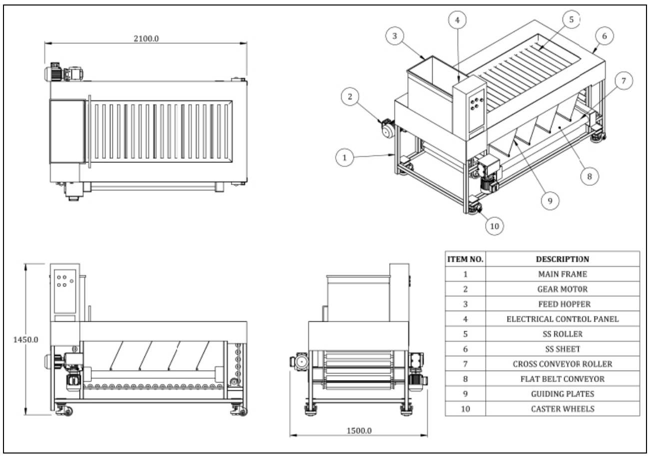


**Fig 1:** Schematic views of Babycorn Grader (Dimensions in mm)

### Grading assembly

The grader roller conveyor assembly consists of 80 stainless steel rollers (length - 609.6mm; diameter - 32mm; material - SS 304). They are connected by chain at both ends using couplings. At a time 4 to 5 baby corns will move in series. Two guiding rollers are provided at both sides of the grading unit. These guiding rollers (2 nos) made of nylon are spirally grooved throughout the length in such a way that the gap between the grading rollers gradually increases after every one-fourth of the grader length while they glide through the grooves. The length of the guiding roller is 1690 mm. The depth of the groove is 15 mm. Total length of the loop of grading rollers engaged in the chain is 6000 mm including the active grading length of 2150 mm. The length of each grading segment is 300 mm. The active grading length is divided into four regions. The clearance between the grading rollers increases from 10mm to 18mm from the point of the feed inlet. Accordingly, the pitch was varied in the guiding rollers. The grading roller chains at the top are covered with SS sheet. The capacity of the feed hopper is 50 kg. Baby corn singulation is desirable and necessary to increase the efficiency of the grader. Transparent acrylic sheets of 3mm thickness are provided at the feed outlet to regulate the movement of baby corn onto the grading rollers so that they move in a single layer for easy grading. Two sprockets at the bottom front end of the grader and two sprockets at the bottom rear end of the grader are provided for the controlled movement of the roller bearing chains. Power is transmitted to the guiding rollers through a bevel gear arrangement (Fig 2).

**Fig 2:** Babycorn Grader

### Collection assembly

The collection assembly consists of cross-conveyor rollers, flat belt conveyor (material-PVC, loop length-2520mm and width-1200mm) and supports. This belt conveyor moves transversely in between the loop of the grading rollers. The machine grades the baby corn into five grades: 10-12mm, 12-14mm, 14-16mm, 16-18mm & >18mm. Guiding plates made of SS304 are provided above the moving belt to guide and avoid injury to the falling baby corns. Two gear motors of 0.5hp are used to operate the grader. The speed of the flat belt conveyor is 0.07m/s.

### Working principle

The cross-conveyor belt motor is operated before switching on the grader. Dehusked baby corns are fed through the hopper. They are fed to the grading rollers in a single layer by the transparent acrylic sheets provided at the feed outlet. While passing through the rollers they are graded based on their size, smaller at first and larger towards the end.

### Performance evaluation

For the performance evaluation of the grader, baby corn was purchased from the local market, Coimbatore, Tamil Nadu. A label was given to each baby corn according to its size to differentiate it from other grades after grading easily. The grader was operated at four speeds – 0.7m/min, 1.1m/min, 1.5m/min and 1.9m/min. In this study, 100 baby corns were used immediately after dehusking in each replication. The number of baby corn dropped at their appropriate port and the total number of baby corn dropped in that respective port were counted. The performance of the machine was evaluated in terms of grading efficiency, grading capacity, and damage evaluation. The experiment was conducted with three replications.

### Grading efficiency

The overall efficiency of the grader was determined by taking the products of the efficiency of different regions of the grader.

$$\text{Overall Grading Efficiency} = \eta_1 \times \eta_2 \times \eta_3 \times \eta_4 \times \eta_5 \times 100\ \%$$

Where

$\eta_1$ – Efficiency of the region 1, in decimal
$\eta_2$ – Efficiency of the region 2, in decimal
$\eta_3$ – Efficiency of the region 3, in decimal
$\eta_4$ – Efficiency of the region 4, in decimal
$\eta_5$ – Efficiency of the region 5, in decimal

The efficiency of each region is the number of correctly graded baby corns divided by total number of baby corns. The input capacity of the grader was determined by considering the time taken to empty the hopper filled with baby corn. Damage was accounted as those baby corns with abrasion on the surface after the grading operation. All the experiments were conducted three times and subjected to Analysis of variance (CRD with equal replications).

## 3. Results and Discussion

### Grader capacity

The size of the baby corn and the grading roller speed are the determining factors of the grader capacity. The lot that contains smaller-sized baby corn (10-12mm size) takes minimum time to reach its destination port. On the other hand, if it contains medium and bigger sized baby corn (18-20 mm size) the time taken for grading is longer. The output capacity of the babycorn grader at different roller speed is shown in Fig 3. The capacity of the grader was found as 63, 99, 108 and 154kg/h at the speeds of 0.7, 1.1, 1.5 and 1.9m/min respectively. The effect of grader speed on the output capacity was found to be highly significant (Table 1).

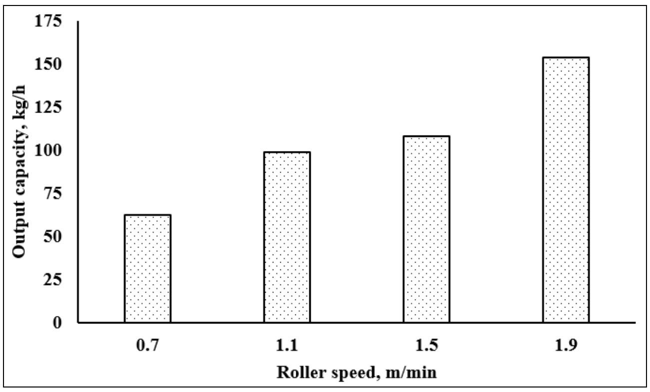


**Fig 3:** Effect of roller speed on babycorn grader capacity

**Table 1:** Analysis of Variance (CRD with equal replication) of output capacity

| Source of variation | Degree of Freedom | Sum of Squares | Mean Square | Computed F value | Tabular F 5% | Tabular F 1% |
|---|---|---|---|---|---|---|
| Grader speed | 3 | 12608 | 4203 | 72.57** | 4.07 | 7.59 |
| Experimental Error | 8 | 463 | 58 | | | |
| Total | 11 | 13072 | | | | |

cv = 7.2%; ** - highly significant

On the other hand, the input capacity of the grader varied from 241 to 714kg/h at the roller speed ranging from 0.7m/min to 1.9m/min (Fig 4). The effect of grader speed on the input capacity was also found to be highly significant as output capacity (Table 2). The input and output capacity was maximum at the grader speed of 1.9m/min and minimum at 0.7m/min. Increased grader speed resulted in increased grader capacity as shown by Dereje Alemu *et al.* (2021) [5]. But Umani & Markson (2020) found that the crank revolution does not have significant effect on the grading capacity for the cylindrical onion grader.

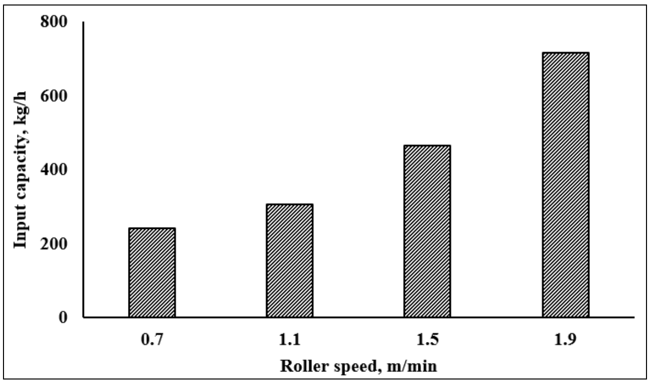


**Fig 4:** Effect of roller speed on input capacity of babycorn grader

**Table 2:** Analysis of Variance (CRD with equal replication) of input capacity

| Source of variation | Degree of Freedom | Sum of Squares | Mean Square | Computed F value | Tabular F 5% | Tabular F 1% |
|---|---|---|---|---|---|---|
| Grader speed | 3 | 399560 | 133187 | 27.89** | 4.07 | 7.59 |
| Experimental Error | 8 | 38206 | 4776 | | | |
| Total | 11 | 437766 | | | | |

cv = 16%; ** - highly significant

### Grading efficiency

Grading efficiency was calculated based on the number of babycorns correctly graded. The size of baby corn in the lot was measured as greater than 12mm. Hence, there was no output in the port 1. The grading efficiency of port 2 was 100% irrespective of the roller speed. At the roller speed of 1.9m/min, the baby corns did not have sufficient time to pass through the respective annular space and as a result, there was no output in port 2 at this roller speed. Valentin *et al.* (2016) [14] also showed that at the higher speed of the grader the movement of potatoes were not uniform which eventually affected the overall efficiency of the grading system. The grading efficiency for ports 3, 4 and 5 ranged between 84.9% to 100%, 83.3% to 92.0% and 87.7% to 93.5% respectively for the roller speed range of 0.7 – 1.9m/min. Increase in grader speed resulted in decrease in grader efficiency as shown by Sai Vinay *et al*. (2017) [12] and Astina Joice *et al*. (2021) [2]. Higher feed rate due to increase in the roller speed also caused less registration of material on the roller, which resulted in reduced grading efficiency as shown by Shahir & Thirupathi (2009) [13] for divergent roller grader.

The overall grading efficiency was calculated by multiplying individual port efficiency. The overall grading efficiency was determined as 84.9%, 75.3%, 70.9% and 68.8% at the grader roller speeds of 0.7, 1.1, 1.5 and 1.9m/min respectively. Results showed that the grading efficiency was significantly affected by the roller speed (Table 3). As the grader speed was increased the overall grading efficiency decreased (Fig 5). At higher speeds, the baby corns were passed on by the rollers to the next slot before getting the chance to pass through. This resulted in the decreased overall efficiency of the grader. Bisen *et al* (2022) [3] showed similar trend for rotary onion grader. On the contrary, Umani & Markson (2020) showed that the crank revolution does not have significant effect on the grading efficiency of the rotating cylindrical screen onion grader for the three grades of onion at non-cushioned condition as well as at cushioned condition of the grading cylinder.

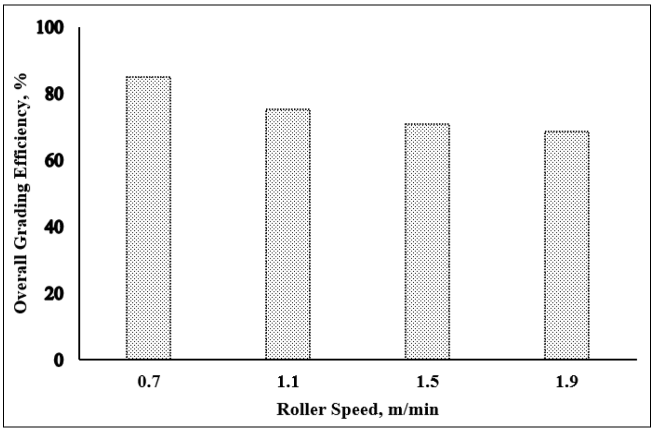


**Fig 5:** Effect of roller speed on overall grading efficiency

**Table 3:** Analysis of Variance (CRD with equal replication) of grader (overall grading) efficiency

| Source of variation | Degree of Freedom | Sum of Squares | Mean Square | Computed F value | Tabular F 5% | Tabular F 1% |
|---|---|---|---|---|---|---|
| Grader speed | 3 | 461.54 | 153.85 | 54.12** | 4.07 | 7.59 |
| Experimental Error | 8 | 22.74 | 2.84 | | | |
| Total | 11 | 484.28 | | | | |

cv = 2.2%; ** - highly significant

Graded fruits were observed visually for mechanical damage. All the graded baby corns were in good condition without any defects such as bruising, skin damage, tissue damage, etc. There were no visual damages to the baby corn during grading because of the smooth running of the roller grader.

## 4. Conclusion

The developed grader is simple in construction and easy to operate and it does not require skilled persons. The movement of the rollers in the pitch is perfect. The optimum speed of the roller was found as 0.7m/min. The overall grading efficiency and the capacity of the grader at this speed were determined as 85% and 60kg/h respectively. The cost of operation was Rs.0.08 per kg. The developed grader can also be used for grading other similar shaped vegetables.

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