Grader: A review of different methods of grading for fruits and vegetables

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Abstract: Grading of agricultural produce especially the fruits and vegetables has become a perquisite of trading across borders. In India mostly fruit growers grade the fruit manually. Manual grading was carried out by trained operators who considered a number of grading factors and fruit were separated according to their physical quality. Manually grading was costly and grading operation was affected due to shortage of labor in peak seasons. Human operations may be inconsistent, less efficient and time consuming. New trends in marketing as specified by World Trade Organization (WTO) demand high quality graded products. Farmers are looking forward to having an appropriate agricultural produce-grading machine in order to alleviate the labor shortage, save time and improve graded product’s quality. Grading of fruits is a very important operation as it fetches high price to the grower and improves packaging, handling and brings an overall improvement in marketing system. The fruits are generally graded on basis of size and graded fruits are more welcome in export market. Grading could reduce handling losses during transportation.

Grading based on size consists of divergent roller type principle having inclination, expanding pitch type, inclined vibrating plate and counter rotating roller having inclination type graders. Weight grading based on density and specific gravity of agricultural commodities. The need to be responsive to market demand places a greater emphasis on quality assessment, resulting in the greater need for improved and more accurate grading and sorting practices. Size variation in vegetables like potatoes, onions provided a base for grading them in different categories. Every vegetable producing country had made their own standards of different grades keeping in view the market requirements.

Keywords: grading, handling, packaging, color sensor, specific gravity, India

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1 Introduction

Agriculture is the back-bone of Indian economy as over 75% of its population is directly or indirectly engaged in this profession. Beyond the traditional agriculture, new trends in cropping pattern have been recognized for changing the status of rural community. Importance of horticulture may not be ignored as the horticulture sector contributes about 12% of value added agriculture. The production of fruits and vegetables at present is 6.0 million tons and 7.0 million tons respectively and will be enhanced to 9.4 million tons and 10.0 million tons, respectively in 2009-10 by Muhammad and Muhammad (2007).

Grading of these minor fruits is considered very important as it can fetch higher price to the grower. Grading also improves packaging, handling and other post-harvest operations. Grading is basically separating

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the material in different homogenous groups according to its specific characteristics like size, shape, color and on quality basis. It saves time and energy in different processing operations and reduces the handling losses during the transportation. Normally fruits are graded manually in the country. Manual grading is an expensive and time consuming process and even the operation is affected due to non-availability of labours during peak seasons (Narvankar and Jha, (2005). The development of graders dated back to five decades ago and the first grader designed was simply a crude slat with a hag attached to the end. Products were inspected on the slat and moved by hand into the bag. These were called slat graders, which led to development of mechanical graders. Grading has been changed very little in the last fifty years. However, the grading process has been fully mechanized. A mechanical grader consisted of a chain conveyor belt, with a bag at the end. Smaller produce fell through the chain, making the grading process easier. In Indian grading is still being done by hand. Labor shortages and a lack of overall consistency in the process resulted in a search for automated solutions. In vegetable grading, the need to be responsive to market demand places a greater emphasis on quality assessment resulting in the greater need for improved and more accurate grading and sorting practices. Size variation in vegetables like potatoes, onions provided a base for grading them in different categories. Every vegetable producing country had made their own standards of different grades keeping in view the market requirements.

2 Material and methods

Various researchers developed many kinds of graders according to market demand and processing aspects. Generally grading is done on the basis of size, shape, weight, color etc. Here a number of studies are demonstrated the application of various types of sorter and grader used in the processing of sorting and grading different types of fruits, vegetables and other agricultural products.

2.1 Size grading

Malcolm and De.Garmo (1953) carried out extensive tests on fruits and potatoes using roller tables with the facility to alter translation speed, roller rotation speed, lighting, scanning and operating position. They set out a number of practical guidelines to achieve optimum throughput and quality. They suggested that potatoes should rotate so that their top surface travels in the direction of translation and if possible should be presented directly to the operator at regular intervals. Translation speed should be 6-9 al per min and rotation speed 6-12 r min^{-1} of translation.

Mack, Larson and White (1956) designated three grades with size range 50 - 57 mm, 57-64 mm, and 64-71 mm. To grade the apples, they developed a sizing belt type grader built from heavy pieces of wire joined together to form square links. The washed apples were passed through another grading unit that separated the apples into three grades. They further recommended foam padding of 25.4 mm thickness to protect the apples from bruising.

Houston (1957) studied new criteria for fruit sizing and noticed that various physical properties of the fruits such as diameter, circumference and cross- sectional area could be used as sizing criteria.

Hunter and Meyer (1958) studied apple sorting methods and equipment, i.e., sorting tables include one with a flat belt, one with longitudinal spiral rolls and one with reverse rotating rubber rollers moving over a plywood frame. Modification as the test proceeded included addition of sorting lanes, variables forward speed of rolls and ultimately a new design called the float roll table. The surface of this table consists of small rubber covered rolls extending across the table. The forward motion is controlled by varying the speed at which the rolls move down the table, and the rotating speed of the fruit is controlled by varying the rate at which the rolls rotate. The cost of labour for sorting a given amount of fruit was lowest for the float roll table and highest for the belt table. When sorting fruits of good quality, the relative efficiency of various types of equipment was apparent.

Van (1965) developed a spiral tomato-grading machine. With this machine the tomato passed down a chute onto a spiral guide and dropped through the appropriate opening of a rotating disc. Up to 1,400 kg can be graded in an hour. Two or three persons are needed to operate the machine.

Burt and Patchen (1966) developed and tested a unitized machine for sorting, brushing, and sizing apples, which used rotating forward moving brushes instead of rollers as in the conventional roller conveyor. The unit includes a conveyor for lifting fruit from the float tank to the brush conveyor. The conveyor includes lane formers, which position the apples for placement on the synchronized brush rollers. Apples remained between the same pair of brushes and in the same lane as they moved through the complete unit for sorting, brushing and sizing. Advantages claimed by the developers include minimum transfer of fruit from one section to another which reduces fruit damage, control of rate and direction of fruit rotation and less floor-space requirement than for conventional grading and sizing lines.

Burt (1967) fabricated a brush sizer and sorter for apple. Very gentle handling was achieved by using soft polyurethane rollers, to lift the fruits from the float tank and to drop them in two lanes on a belt of soft rotating brushes. The first 3 m (10 ft) of travel was past sorters, who removed culls and placed second grade fruit between two lanes. A section followed where brushes rotated at appropriate speeds for polishing and wipping. Then in the sizing section the brushes began to separate, so that the small apples fell between them first and the larger apples at the end. The brushes moved on through cleaning processes and the fruits rolled down a peddled incline to take away belt.

Goodman and Hamann (1968) designed, developed and tested a machine to field size sweet potatoes. The sizing of roots was accomplished by having them riding in a V, which had on open bottom that gradually increased in width from the front to the rear of the unit. The sides of V were made up of round, clear vinyl plastic belting driven by step one sheaves keyed to a shaft mounted in pillow block bearing and driven by roller chain from a hydraulic motor. The belts near the top of the V have a greater linear velocity than those near the bottom. The effect of this differential speed was to cause any object, such as a root, that fall on the sizing belts to rotate until its long axis was parallel to the belts. At this time the root would be roles to the bottom of the V. The capacity of the unit was 160 bushel h^{-1} with belt speed of 27.5 m min^{-1}. Damage was minor and within acceptable limits, when passing over sizing mechanism. Potatoes were graded in 2.5 to 6.0 cm and 5.0 to 15.0 cm grades.

Hunter and Yaeger (1970) conducted a series of tests on a roller table and considered variables like feed rate, percentage defective tubers, speed of translation and rotation of the rollers, as well as direction of rotation, manner of removal of tubers and lighting levels. It was concluded that the feed rate could be adjusted to allow removal of defective tubers. Considering the mean weight of tuber as 160 grams, around 6250 defective tubers removed each hour. Rollers were reversed so that the top surface of the potatoes rotated in the direction of translation at 6 r m^{-1} of translation. At defect level of 20% a lower rotation speed was used. In a typical test above 90% of defective tubers were removed when the flow rate was about 450 potatoes min^{-1}. In the test they correlated the feed rate, translation of crop and rotation of the rollers to remove the maximum defective tubers.

Grover and Pathak (1972) designed and developed a wire belt type of potato sizer capable of sizing the tuber into four sizes. The prototype was operated with 2 hp electrical motor. The output was found to be 20 to 24 quintal h^{-1} with 1% to 10% of brushing and about 94% of sizing efficiency.

Brantley, Hamann and Whitefield (1975) developed a multiple belt adjustable V-size grader for use in stationary sweet potato and cucumber packing line application and tested for reliability and endurance in commercial operation. Results showed that product damage was negligible and average sizing accuracy (with wobble) was 95% to 98% for sweet potatoes and 94% for cucumbers. Best results were obtained with a sizing belt speed of 1.07 m s^{-1}, orienting the belt at velocity ratio 2.25: 1, and product feed rate less than 2040 kg h^{-1}, though feed rates up to 2610 g h^{-1} did not produce excessive error.

Verma and Kalkat (1975) designed and developed an expanding pitch rubber spool potato sizer. A prototype of potato sizer comprises of mainly a sizing conveyor containing rubber spool and two identical driving rollers with helical groves of gradually increasing pitch. The performance of expanding pitch rubber spool potato sizer was studied at three different speed of sizing bed corresponding to the helical shaft speed of 190, 110, and 75 r m^{-1}. The result showed that there was no appreciable difference in the percentage variation of tuber weight collected in different size grade at different speeds. The output of potato sizer was found to be about 25 bags per hour. The overall performance of the sizer was found to be quite satisfactory.

Morgon and Constantin (1976) developed a compact laboratory seed separator to operate without the limitation of screens. The separator grader was designed primarily to sort kernels of cereal grains and it adjusted to permit selection of numerous size classes on ascending order. The range of each size class can be change to meet a requirement for a variety of kernel dimensions. The divergent rollers were mounted side by side in an inclined position. One roller was rotatable while the other one was stationary but adjustable so that the spacing between the rollers can be controlled. Seeds were metered through a vertical plastic cone to the high-end junction of the paired rollers. The seed moved down the inclined-paired rollers for separation according to size range. The roller speed can be varied by changing diameter of the v-belt drive sheaves. The angle of inclination of the paired rollers can be varied through a range of 0 to 7 degree of control flow rate of seed along the roller length. The separator grader proved effective in uniformly sizing cereal grains.

Naugle and Brien (1976) carried out engineering analysis of a mechanized fruit grading table. The results of the study showed that by using the mechanized table system, saving in the amount of labour requirement for manual grading would be realised. Use of spiral drum sub-sampler could effectively replace the interim.

Bryan (1978) reported that the mechanically assisted manual grading process improved effectiveness of removal of unwholesome or “cull” fruit during the unloading of oranges at a processing plant. In this process, most culls were separated mechanically by differences in bouncing behavior into a side stream containing less than 15% of the total fruit flow. Only the small side stream then required manual grading before storing fruit in bins. When this process was used, efficiency of manual grading was almost twice that of conventional procedure because the stream requiring inspection was small and the concentration of the culls was 5 to 15 times that in the original fruit. The process was demonstrated on 1/3 commercial scale in a pilot fruit receiving system at a citrus processing plant.

Frank et al, (1978) developed a research tool for sorting strawberries by size. A sorter consisting of a box shaped frame 47 × 47 × 62 cm, with five removable drawers was constructed of 6 mm clear Plexiglas. The top drawers had a mesh of 3.81 cm diameter and the bottom one 1.91 cm.

McClure and Holmes (1979) investigated an inclined vibrating plate as tomato sorter. Separation into red and green fractions was successful for an angle of tilt of 40° at a frequency of 72 h and amplitude of 0.18 cm, because the green tomatoes bounced down while the red tomatoes slided up the incline.

Bryan, Jenkins and Miller (1980) reported that the mechanically assisted manual grading was effective for sorting oranges that contained higher number of decayed fruits that could be removed by conventional grading procedure at usual unloading rates. A mechanical separator diverted most of the unwholesome orange by differences in bouncing behavior into a small side stream that contained less than 10% of the original fruit stream. Only the side stream required manual grading before storing fruit in bins. The process was particularly effective for grading loads of mechanically harvested oranges that contained 75% decayed fruit.

Carlow (1980) designed a roller conveyor and fitted an electronic aid, when unwanted potatoes were touched by hand held wand and a vertically polarized radio frequency signal was emitted. The signal was received by a matrix of longitudinal and transverse coils situated tinder the roller deck. Changes in voltage in the coils were caused when the wand was energized and used to identify the coil intersection nearest to the wand. A signal was transferred to shift registers, synchronized with the grading table motion to operate a solenoid-actuated rejecter linger when the unwanted potato reached the end of the conveyor. In tests with rubber balls marked to signify a damaged area, it was found that in comparison with a standard roller table, the semi-automatic grader gave 20% improvement in grading efficiency, with a 15% defect level and from 50% to 60% improvement at 20% defect level.

Dickens (1980) constructed a peanut sizer using the divergent roller principle for size classification, in which the product were metered at the high end junction of the inclined paired rollers and moved down. Speed and inclination of the rollers effected speed passage through the varying clearance width between the rollers. The size classes were collected in the catch pan.

Hutchison and McRae (1980) developed a high throughput variable aperture grader with parallel rollers. That was the simplest sizing machine developed for agricultural produce. These had been popular for some time for crops such as carrots and parsnips, which were of cylindrical or tapered profile and would tend to be damaged and poorly sized through a square-mesh screen. Its efficiency when grading the variety Mark Piper compared with a hand operated parallel bar riddle was 96.8% at 12 t h^{-1} throughput, but in comparison with a standard square-mesh riddle an efficiency of only 85% was achieved at the same output.

Singh (1980) developed differential belt speed expanding pitch type potato grader. The main components of the grader were feed conveyor, frame, grading unit, collection platform and power transmission unit. The grader required 1 hp to drive its various components at full load. The maximum separation efficiency at optimum speed (35 r min^{-1} of grader shaft, 4.4 m min^{-1} of belt speed, 17.24 quintal h^{-1} of feed rate) was found to be 87%.

Gadakh and Gangarde (1981) tested the groundnut grader for effect of speed and angle of inclination of rollers on feeding rate and separation efficiency. They graded the groundnut pods of varieties JL-24 and SB-11 into four different size grades at various combination of speed (360, 440 and 560 r m^{-1}) and angle of inclination (3.5°, 6.0°, and 9.0°) of rollers. They observed that as the speed and angle of inclination of rollers increased, the feed rate increased in variety JL-24. However, this relationship was not holding well in variety SB-11. While separation efficiency decreased, angle of inclination of rollers increased. The overall efficiency of the grader was observed to be 71.2%.

Akinaga and Khoda (1982) developed a sorter in which sorting was done on the basis of dimension of the fruits and vegetables (e. g. length, width). Compared with manual sorting accuracy of the sorter was found to be satisfactory.

Farher and Bruter (1983) described apparatus for sorting fruit and vegetables. It comprising rollers mounted on traction elements, guides and an inclined board. To reduce susceptibility to damage of the fruit, by preventing them from jamming the output section, there was a bracket in the output region turning the rollers.

Firus and Unbekannt (1985) described the potato grading accuracy. Grading characteristics at the limit of the set size accuracy were examined in terms of tuber size range. It was noted that separation function is independent of the size composition of the tuber mixture to be separated. Separation function was used to demonstrate that criteria of separation accuracy (proportion of undersized tuber mixture in a graded lot, losses of market size tubers, overall grading accuracy and degree of separation) are dependent upon the size composition of the mixture to be separated.

Baab and Rohlfing (1986) developed a rational method for sorting sweet cherries. An inclined, adjustable sorting table was illustrated and described. It increased sorting efficiency by 60 to 70% compared with previous methods. Using a moving belt for fruit sorting worked well technically but sorting decreased after two to three h as the sorters became tired.

Rusalimov (1986) studied grading walnuts according to the minimum diameter of their mean cross section. A prototype grader consisting of two inclined, counter-rotating rollers was constructed. Optimum parameters for self-cleaning and nut transport were determined. A roller diameter greater than or equal to 96 cm and angle of inclination 12.2° were required to achieve grading with an accuracy of 90.32% at minimum nut diameter of mean cross section 21.3 to 35.6 mm.

Graders with two and four channels processed 2 and 4 t nuts per shifts, respectively.

Davenel et al, (1988) designated four quality grades extra, No. 1, No. 2, and No. 3, having size range >65 mm, 60-65 mm, 55-60 mm and <55 mm respectively.

Posselius and Cox (1988) developed portable melon sizer for research plots. It was designed and tested by using divergent roller concept to grade cantaloupe melons. Grading made by an experienced scientist, an inexperienced novice and the mechanized sizer, were compared. The mechanical system was significantly faster than the novice and made a similar number of sizing errors to the expert.

Anonymous (1989) developed a hand operated orange size grading machine which was based on tapering roller principle. The taper rollers required for this grader was fabricated from mango wood. A handle was provided to rotate the rollers meshed by gears at one end, and to operate the feeding mechanism. The collecting chutes were made out of gunny bags. Rest of the mechanism was similar to the separation part of the previous machine. The total 160 oranges consisting of 40 of each four grade were mixed and fed to grader. The distributed lot was collected and passed through the measuring rings, to confirm its size individually. Six replications were given with same fruits. The results showed that the new orange grader has around 80% separation efficiency with 5000 oranges per hour capacity.

Nevkar (1990) developed and tested the divergent roller type grader for effect of roller speed, angle of inclination of rollers, gap between the rollers on capacity and separation efficiency. The fruits were graded into four different size grades at various combination of speed (195, 216 and 278 r m^{-1}), angle of inclination (4.59°, 5.6° and 6.1°) of rollers, gap between the rollers (2.83- 5.00, 2.84-5.20 and 2.87-5.40 cm) for lemon fruits and (3.07-7.00, 3.13-7.20, and 3.16-7.40 cm) for chiku fruits. He observed that the capacity of the machine increased with increase in roller speeds, inclination of rollers and gap between the rollers. A decreasing trend was observed for separation efficiency with increase in roller speed, angle of inclination and gap between the rollers for both fruits. The overall separation efficiency for lemon fruits was 71.71% and 66.75% for chiku fruits. The overall sorting capacity for lemon fruits was 603.94 kg h^{-1} and for chiku was 1,189.92 kg h^{-1}.

Shyam et al. (1990) designed and developed a power operated sieve type potato grader that was capable of sorting potatoes into 4 or 5 different sizes or grades. The grader gave high sizing efficiency and 20-25 q h^{-1} throughput capacity. The grader employed 10-14 attendants and achieved 80%-90% efficiency with average tuber damage within range of 2%. High labor requirement and re-orientation of the product in sieve opening were considered as problems and a little bit higher skin bruising was observed

Suppavit and Butta (1995) described four grades of onions on basis of size. They developed a belt type grader to sort exported onions on basis of size. A Belt conveyor was also designed to carry onions from a container to a set of metering device. The capacity of' this machine was &tin/lined by the velocity of the belt. The grader graded the onions into four sizes <70 mm, 70-80 mm, 80-90 mm and >90 mm. These sizes were acceptable for abroad marketing. They further evaluated its performance at different belt velocities and lend the optimum velocity 0.13 m s^{-1} of the belt for maximum grading capacity of 3,150 kg h^{-1} with an error of 2.46%.

Tariq et al, (1995) described four grades of potatoes for marketing purpose i.e., extra-large size (>70 mm), over size (55-70 mm), medium size (35-55 mm) and small size (C 35 mm). Both the researchers had considered the same range (17 to 70 mm) but one had designated four grades while other had designated five grades.

Patil and Patil (2002) designed, developed and tested performance of sapota fruits grader. The machine developed was of divergent roller type. The effect of roller speed and gap between the rollers on capacity and separation efficiency was also studied. Three rollers speeds (300, 360 and 450 r min^{-1}) and three different gap between the rollers (3.0-5.5, 3.3-6.5 and 3.6-7.5 cm) were taken for testing the performance of machine. The maximum capacity of 1,800 kg h^{-1} and minimum capacity of 1,152 kg h^{-1} were obtained for sapota fruits. The overall machine sorting capacity for sapota was

1,727 kg h^{-1}. The maximum and the minimum separation efficiency was 87% and 54%, respectively. The overall separation efficiency of the machine was 72%.

Anonymous (2003) designed and developed a divergent roller type of onion grader Separation of onion is achieved on the basis of size. The roller with spacing of 35-80 mm from feed end to discharge end between the rollers. The spacing between the roller increases feed end to rear end. The onions were graded into four different grades. The capacity of the grader was 500 kg h^{-1}. Sized onions passing between the rollers were collected in separate compartment.

Anonymous, (2004) designated three grades on basis of size for local market and these grades were large (>60 mm), medium (40-60 mm) and small (20- 40 mm) while Maharashtra State Agricultural Marketing Board made a standard for grading of onion on basis of size and designated five grades 25-35 mm, 35-45 mm, 45-55 mm, 55-65 mm, and above 65 mm.

Ghuman and Kumar (2005) studied on development of low cost rotary disc size grader for fruits and vegetables. Grading of fruits and vegetables is an important operation affecting quality, handling and storage of produce. Manual grading is costly, time-consuming and inefficient. A low cost, on-farm rotary disc size grader was designed and fabricated for grading spherical fruits and vegetables using rubber balls of different diameters in the laboratory. It was observed that the disc speed of 60- 70 r min^{-1} was the most suitable for proper separation of different grades. The grader shall be tested for various fruits and vegetables both in laboratory as well as in the field.

Mangaraj et al, (2005) studied on a stepwise expanding pitch fruit grader based on the principle of changing the flap spacing along the length of movement of fruits. The main components of the fruit grader are grading unit, elevator feeding unit, inspection platform and power transmission system. The grading unit consists of two tracks of conveyor chains, matching sprockets, stainless steel flaps, conveyor supporters, flap space adjusting mechanism, power source, power transmission system and fruit collection trays. The elevator feeding unit is provided for constant and uniform feeding of fruits into the grading unit. The Inspection plat form is provided for removal of damaged, diseased and unwanted fruits before they are fed to the elevator feeding unit. Cushioning material has been glued to the inspection platform, fruit collection tray and flaps to avoid impact damage at the time of grading. The grader has the provision to separate fruits into four grades by adjusting flap spacing between 45 to 140 mm. Testing of the fruit grader showed overall grading efficiency of 91.50% and 88.50%. For sweet lemon and orange, respectively. The capacity of the grader was 3.5 t h^{-1} at grading conveyor speed of 6 m min^{-1}.

Ashraf et al, (2007) studied on the design, development and performance evaluation of fruit and vegetable grader. Three functional units were fabricated: take-in conveyor, grading unit and take-away conveyor, and all mounted on a main frame. For optimizing feed rate of the grader, three take-in conveyor speeds 10, 15 and 20 m min^{-1} were selected to load the crop on the grading unit at 6, 9 and 12 t h^{-1} respectively. A drive mechanism with three speed levels 25, 50 and 75 r min^{-1} were developed to accommodate the different feed rates. To convey the graded produce to the packing point take-away conveyors were developed that operated at three speeds, 5, 10 and 15 m min^{-1} without causing the mutual collusion of the falling produce from grading unit. Increased grading speeds of about 75 r min^{-1} resulted in increased damage index whereas higher take-in conveyor speeds of about 20 m min^{-1} resulted in more grading errors. Effective human supervision was found important for ensuring smooth operation of the grader. The average grading charges were about Rs.4 per 100 kg of produce.

Ukey and Unde (2010) developed a sapota fruit grader. In order to increase the output of fruit grading and save time and labour, a sapota fruit grader based on divergent roller type principle was designed and developed. The best combination of roller speed, its inclination and roller gap was found to be 223 r min^{-1}, 4.5º and 38 to 64 mm, respectively for highest efficiency of 89.5%. The capacity of machine was 1,440 kg h^{-1} and costed Rs.11, 450/- (without electric motor).

2.2 Weight grading

Jager et al, (1958) developed an early type of weight grader, which consisted of a rotating hub carrying a number of radially disposed cups on single leaf spring arms. The leaf springs responded according to the weight of potato, which was released into the appropriate outlet by a cam rail tipping arrangement. He plotted a graph of weight against diameter, pointing out that weight increases as the cube of the diameter.

Stephenson (1974) developed a handling and sorting system for certain fruits and vegetables. A spiral roller was constructed using a roller of 2-inch diameter aluminium pipe. Foam rubber spirals were tried, but counterbalance weight until such time as the weight of fruit causes the beam to tip, discharging the fruit into padded chutes in weight categories.

Rana and Chauhan (1985) described four grades and these grades were designated on weight basis. Mostly the researchers designated grades to potatoes on basis of size as per demand of the market as described by Roy, Wohab and Mustafa (2005). They designated four grades to potatoes (<28 mm, 28-40 mm, 40-55 mm and >55 mm.

Zaltzman and Verma (1985) studied quality sorting of agricultural products based on density and reviewed the relationship between quality and density of agricultural commodities and of current separation and sorting technologies. The potential of quality sorting with fluidized bed separation for small density differences was described.

Meylor and Finn (1994) described a flotation grading system for operating fruit or vegetable pieces with different specific gravity. In which desirable pieces have a different specific gravity from the undesirable pieces, and all have a specific gravity about the same as that of water. The pieces were placed near the surface of a body of water in which a cloud of tiny air bubbles was maintained. As the bubbles floated to the surface, they encountered the articles and slightly increased their bounce. The increase in bounce was slight and uniform, so those particles having a density slightly greater than that of the water retained at the water surface, while those of slightly greater density sank to the bottom. The cloud of air bubbles was at atmospheric pressure to emerge from operation in a rapidly spinning rotor.

Omre and Saxena (2003) designed and developed a multi-fruit grader that was capable of grading fruits into four grades (A, B, C and D) on basis of weight. Grade A (>200 g), Grade B (150-200 g), Grade C (100-150 g) and Grade D (<100 g). The performance of the grader was evaluated at different speeds (5, 10, 15, 20, 25 and 30 r min^{-1}) and was found satisfactory at carrier speed 12 and 15 r min^{-1} with overall grading efficiency about 96%.

Badhe, Singh and Bhatt (2011) studied on development and evaluation of mango grader. A computerized grading machine was developed and evaluated to grade Alphonso mangoes on weight basis in five grades. Logistic software was developed to run the grader. The performance of the grader was evaluated at four speeds (480, 600, 720 and 840 m s^{-1}), four microprocessor settings (B1, B2, B3 and B4) and their effect was observed on five grades of mango viz., Grade I (326-375 g), Grade II (276-325 g), Grade III (226-275 g), Grade IV (176-225 g) and Grade V (< 175 > 376 g) for single lane. The statistically analyzed data showed maximum capacity of 950 kg h^{-1} with maximum grading efficiency of 95.13% at 720 m s^{-1} speed and B4 setting. The cost of manual grading was Rs. 350 per t as against Rs. 190 per t for the grader.

2.3 Screen grading

Dickens (1980) studied the effect of screening and screen opening on the market value and quality of farmer's stock peanuts. Three samples of Virginia type farmers stock peanuts were collected at three different locations in North Carolina and were sized over rollers spaced 4.68, 6.25, 7.81, 9.38, 10.94 and 12.50 mm apart. The amount of foreign material, loose-shelled kernels and pods, which rode each spacing was determined. The kernels shelled from each segregation of pods and the kernels in each segregation of loose shelled kernels were graded to determine the size of distribution, the amount of splits, the count per pound, the amount of damage and the amount of minor defects. The potential market value and quality of shelled peanuts produced from the farmer's stock peanuts that rode each roller spacing was also determined. The effects of screening farmer's stock peanut were studied in relation to the quality of shelled peanuts for edible purposes.

Balls (1986) described the screen or sieve type grader i.e. the perforated and mesh screen, which is the commonest method for two dimensional grading and, like the bar screen, is made either as a rigid screen or in the form of a conveyor. The grader screens normally have square holes, but for some crops, other shapes are preferable, for example, slotted for narcissus bulbs and round for tulips. He further described that set of screens can easily be changed to obtain a wide range of grading capability of the grader.

Hann and Van (1987) studied grading and sorting of potatoes using a square mesh riddle system with reference to uniformity, accuracy, damage and capacity. Quality sorting by hand selection, semi-automatic and electronic methods was discussed. Ergonomic aspects of hand sorting, densities of potatoes to be sorted, disposal arrangement for rejecting potatoes, positioning of inspectors, sorting table construction and attainable sorting capacity were included.

Shyam and Singh (1988) studied on sorting of potatoes into different size graded by mechanical sieving. They studied the effect of various parameters on the performance of the experimental power operated sieves for sorting potatoes into four different size grades. Results indicated that screen efficiency and blinding of sieves increased with decrease in sieve speed, stroke length and sieve slope. Screen efficiency was also increased with feed rate in the lower range but decreased as the feed rate was progressively increased. High screen efficiency upto 93.67% was obtained by providing little manual assistance to take care of blinding of sieves. However, tuber damage was consistently high.

Shyam and Singh (1988) developed a simple indigenous manual and power operated mechanical size grader with and without feed conveyor attachments which used successfully for sorting seed potatoes at the Central Potato Research Institute, Simala. The machine worked on the conventional principle of sieving. It comprised a steel frame, a set of two or three oscillating sieves, a power transmission unit, a stationary sieve feeding chute, a sorting platform and a bag filling device. The average field performance, power source, labour requirement and estimated operational costs of the manual and power operated size graders were noted.

Shyam, Singh and Singh (1990) designed and developed a potato grader. Design consideration, constructional details, method of operation and performances have been reported. On an average, the grader sorted 20 to 25 q h^{-1} of seed potato into 4 to 5 sizes employing 0 to 14 attendants. The screen efficiency of the oscillatory sieves ranged from 80 to 90% and average tuber damage was to be within 2%.

Doriaswatny (2000) developed a sieve type grader for grading groundnuts into three different sizes. The output capacity was 600 kg h^{-1} and was powered by one horsepower 3-phase electric motor. Re-orientation of pods in sieve holes was observed that required modification in shaking system. Adler reviewing the literature it was concluded that sieve type graders faced a same problem of sieve hole blocking.

Roy, Wohab and Mustafa (2005) developed a low cost potato grader. There were three sieves at an angle of 15° with the horizontal and sieves were made of rubber impregnated al wires. The grader was capable to size the potatoes into four sizes with the capacity of 2,030 kg h^{-1}. Trapping of potatoes in the sieves was observed and to eliminate the potato trapping, a mechanism for re-orientation of potato tubers was recommended.

Narvankar and Singh (2005) studied on rotating screen grader suitable for fruits like lemon, ber, aonla to grade the samples into 4 grades. The grader was tested for capacity and optimum grading performance as a function of rotating speed of screen, diameter of screen, exposure length and input each at four levels by using second order response surface design in 80 design points. Capacity of the grader varied from 45 to 327.27 kg h^{-1} for lemon, 43.63 to 464.51 kg h^{-1} for aonla and 46.75 to 436.36 kg h^{-1} for ber. The maximum grading efficiency for lemon, aonla and ber was found to be 79%, 93.8% and 97.96% respectively.

2.4 Electronic color grading and reflectance grading

Powers and Gunn (1953) developed a successful experimental machine for sorting lemons colorimetrically into four classes prior to storage. There was no significant difference in spoilage between the machine stored and hand sorted fruits. The methods and apparatus used could be applied to sorting other fruits and vegetables.

Heron and Zachariah (1974) studied an automatic sorting of processing tomatoes. A wide belt high capacity concept of color sorting was introduced. The sorter viewer observed three possible states, unriped tomato (rejects), riped tomato (no action) and background. The amount of background observed by the viewer when a tomato was only partially in view was determined by the inherent focusing of a sorter-viewer. Test results showed that it was possible to increase the scanning speed (for increased capacity) to desired levels without detrimental effects on sorting accuracy.

Stephenson (1974) developed an electronic detection and high-speed rotary gate controls for sorting machine of harvested tomatoes. First on a sequence of operation, a means of singulation of fruits was accomplished, followed by scanning of each fruit for color by reflected light. Photocell sensors, an integrated circuit comparator and a controlled rotary gate detected and rejected green fruit at speeds up to eight fruits per fruit per channel. Sorting accuracies of 98 to 95% were obtained, sorting speeds up to six fruits per second per channel. Performance at higher speeds showed reduction in sorting accuracies.

Anonymous (1980) reviewed an electronic color sorter for sorting of fruits. In ‘Electrosort’ system of the DeccoTibelt Company, for hard fruit, as tomatoes, peaches, plums, avocados, potatoes, lemons, papayas, and pineapples, washed and/or waxed fruit comes into the color sorter scanner, separated into individual container for each fruit and weighted. The greater than 12 size broke and 5 color separations allowed sorting into up to 48 selection standards, with automatic packing and completely accurate grading. The food machinery corporation system used an electronic scanning and a central control unit also receiving weight and size data and steering the fruit (in individual cups) towards a packing line at a speed of 300 cups per lane per min.

Kodaira (1982) described a fruit and vegetables sorter with a video sensor. The system is mainly composed of a color sensor, which differentiates the color of materials, and the television camera, which differentiates shape and size of material and mechanical instruments for classification of materials and for calculation control.

Barresi and Blandini (1988) developed automatic citrus grading devices. An automatic machine graded oranges in real time, according to quality and appearance by optical methods. Laboratory and field trials results suggested that it was possible to reduce up to 70% workers in citrus pack-houses.

Delwiche, Tang and Mehlschau (1989) developed a single lane firmness sorting system, which conveyed fruit horizontally at constant speed (76.6 cm s^{-1}) and caused them to impact on a rigid surface. Approximately 74% of the peaches were sorted into correct firmness range.

Gaffney (1973) studied citrus grading by automation. The technique involved measuring the amount of light reflected from skin defects compared with that reflected from the normal fruit surfaces. In studies on light reflectance characteristics of citrus fruits with a double beam recording spectrometer and reflectance attachment, a reflectance difference of at least 15% between defective and normal fruit surfaces was recorded. For each fruit variety a single wavelength bond was formed that could be used for detecting difference between the various defects and the normal fruit surfaces.

Nahir and Ronen (1986) introduced tomato grading by impact force response. Some theoretical consideration based on Newton’s laws of motion was presented, a mathematical model for tomatoes at time of impact was discussed and solutions for measurements and grading error evaluations were proposed. A mechanical separation system (conveyor, measuring impact or separating mechanism, data processing section) indicated that the impact force response method was equal or superior to conventional methods for grading tomatoes in terms of weight, stiffness and color.

Noordam and Otten (2000) studied on high-speed potato grading and quality inspection based on a color vision system. A high-speed machine vision system for the quality inspection and grading of potatoes has been developed. The vision system graded potatoes on size, shape and external defects such as greening, mechanical damages, rhizoctonia, silver scab, common scab, cracks and growth cracks. A 3-CCD line-scan camera inspected the potatoes in flight as they passed under the camera. The use of mirrors obtained a 360-degree view of the potato and the lack of product holders guaranteed a full view of the potato. To achieve the required capacity of 12 t h^{-1}, 11 SHARC Digital Signal Processors performed the image processing and classification tasks. The total capacity of the system was about 50 potatoes per second. The color segmentation procedure used Linear Discriminant Analysis (LDA) in combination with a Mahalanobis distance classifier to classify the pixels. The procedure for the detection of misshapen potatoes uses a Fourier based shape classification technique. Features such as area, eccentricity and central moments were used to discriminate between similar colored defects. Experiments with red and yellow skin-colored potatoes showed that the system was robust and consistent in its classification.

Ahmad et al, (2010) studied on development of automatic grading machine prototype for citrus using image processing. The grading machine consists of a rotating fruit feeder, a belt conveyor, a color CCD camera placed in an image acquisition chamber, four openings each for a different grade of citrus, four collecting boxes to accommodate the graded citrus, a logic control panel, a computer with an image frame grabber, and developed software to run all the installed hardware. The performance test for the grading machine then was conducted, and the result of citrus classification was observed visually to determine the performance of the machine. The testing results showed that the machine prototype could work properly, and the classification of citrus could be done based on the fruit size as conventionally done, added by the skin color of citrus as an improvement to the manual sortation.

Khojastehnazhand, Omid and Tabatabaeefar (2011) studied on development of a lemon sorting system based on color and size. Grading systems give us many kinds of information such as size, color, shape, defect, and internal quality. Among these color and size are the most important features for accurate classification and/or sorting of citrus such as oranges, lemons and tangerines. Basically, two inspection stages of the system can be identified: external fruit inspection and internal fruit inspection. The former task was accomplished through processing of color images, while internal inspection required special sensors for moisture, sugar and acid contents. In this paper, an efficient algorithm for grading lemon fruits was developed and implemented in visual basic environment. The system consists of two CCD cameras, two capture cards, an appropriate lighting system, a personal computer and other mechanical parts. The algorithm initially extracted the fruit from the background. The samples of different grades of lemon were situated in front of the cameras and were calibrated off-line.

2.5 Miscellaneous grader

Malcolm and De.Garmo (1953) tested a Roller table grading mechanism to grade fruits and potatoes. They recommended several practical guidelines for optimum throughput and quality to be achieved. They suggested that potatoes should rotate so that their top surface traveled in the direction of translation and if possible should be presented directly to the operator at regular intervals. They further recommended 6-9 m min^{-1} translation speed and 6-12 r m^{-1} of translation speed. Surprisingly, the percentage of defects appeared to have little adverse effects on inspection efficiency, but for each type of defect sought in the sample, a drop of 3% in efficiency occurred.

Srivastava, Shukla and Srivastava (1995) developed a potato-cum-onion grader. It consisted of a frame, an elevator, feed conveyor, a sizing conveyor, an intermediate receiving conveyor, a sizing conveyor with rubber spools and power transmission system. Sizing accuracy was better round shaped varieties than oblong or irregular shaped varieties.

Liu (1989) developed a self-propelled sizing machine that consisted of three layers of inclined rotating parallel rollers supported at each end. The spaces between the rollers were such that the undersized fruit passed through to the second layer and the larger fruit was retained and rolled to the end of the unit for collection. The second and the third layer of rollers functioned exactly the same as the first layer. Four different size classes of fruit could be separated with this unit. Each layer of rollers was constructed as a module and could be replaced easily. Therefore, the same machine could be used for sizing different tree fruit by changing the roller module.

3 Conclusions

Normally fruits are graded manually in India. Manual grading is costly, time-consuming and inefficient. Grading of fruits and vegetables is an important operation affecting the quality, handling and storage of produce. Grading systems give us many kinds of information such as size, color, shape, defect, and internal quality. Among these color and size are the most important features for accurate classification and/or sorting of citrus such as oranges, lemons and tangerines. A rotating screen grader is suitable for fruits like lemon, ber, aonla etc. Citrus grading is normally achieved based on external visible criteria including size, shape, and color of the fruits. Grading based on size is easy and less expensive according to other methods of grading and used for grading of potato, onion, tomato, apple etc. Weight grading of fruits and vegetables based on its density and specific gravity. Electronic color grading is done for highly perishable fruits and vegetables. This method is costly but higher accuracy of grading. Electronic color grading and reflecting color grading is used for apples, tomatoes, papayas, pineapples grading.

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