Cooling Carcasses

- **After slaughter**, different processing techniques are used for different animal species:
  - e.g. after evisceration pigs are **dehaired** and other animal carcasses (sheep, goats, cattle, rabbits, etc.) are **skinned** to remove all damaged or contaminated parts and leave the carcass in a suitable condition for **cold storage**
- **Rigor mortis (postmortem rigidity)** process usually begins within a few hours after death, peaks around 12 hours, and then gradually **disappears** after 24 to 48.
  - Animal carcasses **should not be cooled** immediately after slaughter to allow time for **rigor mortis** to take place
  - Rigor is completed in cattle after 12-24 hours and is resolved by periods that depend on the temperature: 10-13 days at 0°C, 4-5 days at 10°C, **18-24 h at 15°C** , at 20°C and 10-11 hours at 30°C
  - Obviously if meat has to be sold within a few hours of slaughter it is still in **pre-rigor or rigor**, and the **tough meat** has to be cooked longer with some loss of nutrients.

- Cooling the carcass during **anaerobic respiration** reduces **drastic pH reduction** and produces the required texture and colour of meat

- However, rapid cooling to temperatures below 10-12C before anaerobic glycolysis has ceased causes permanent contraction of muscles known as '**cold shortening**', which produces undesirable changes and toughening of the meat

- The **ideal** storage temperature for **fresh meat** is just above its freezing point at around -1 C, which gives a storage life of up to 21 days for beef, 7-21 days for veal, 10-15 days for lamb or goat meat and 7 days for offal

- Control over the temperature of storage is the most important factor that affects the rate of deterioration of **fish and seafoods**

- The quality of **white fish** remains acceptable for 10-20 days after capture if it is kept at 1-2 C with **ice**

- Iced **fatty fish** such as herring remain acceptable for a shorter time (4-6 days)

- **Seafoods** (e.g. shrimps, lobsters, crabs, mussels, clams, squid, scallops, etc.) are stored at or near 0 C until they are sold or processed

- The **speed** and **humidity** of the air in a meat store are important:
  - high airspeeds increase **weight losses** due to evaporation unless the relative humidity is also high
  - but **saturated air** causes moisture to **condense** on the carcass surface, which promotes the growth of **moulds** and **bacterial** slime
  - Air should have a RH of ≈90%, moving at a relatively **slow speed** (e.g. 0.5 m /s) to give rapid cooling without the risk of condensation
- The aim is to achieve a **deep muscle** temperature of 6-7 C within 12-16 h for pigs, within 24-30 h for sheep, and 28-36 h for beef carcasses

Cleaning Foods

- Different **contaminants** may be found in raw foods originated from different sources (Table 2.3)

- **Cleaning** removes contaminating materials to leave foods in a suitable condition for sale in the fresh market sector or for further processing

- Cleaning should take place at the **earliest opportunity** in a process to prevent damage to subsequent processing equipment by, e.g. **stones**, **bone** or **metal fragments**

- The early **removal of food pieces** that are contaminated by **microorganisms** also prevents the spread of infection to uncontaminated pieces and reduces the risk of total loss during subsequent storage or delays before processing

- **Methods of cleaning:**
  - **Wet** procedures (e.g. soaking, spraying)
  - **Dry** procedures (separation by air, magnetism or physical methods)

Table 2.3 Contaminants found in raw foods

Contaminant	Examples	Potential sources
Ferrous and nonferrous metal particles	Filings, nuts, bolts	Mechanised harvesting, handling and processing equipment
Mineral	Soil, engine oil, grease, stones	
Plant	Leaves, twigs, weed seeds, pods, skins	Crops or animals
Animal	Hair, bone, excreta, blood, insects, larvae	
Chemical residues	Fertilisers, herbicides, insecticides or fungicides	Incorrect application or overuse
Other chemical	Metals (e.g. lead, mercury, arsenic), acrylamide, dioxins and polychlorinated biphenyl compounds (PCBs)	Accumulation in the fat of animals
Microbial cells	Bacterial soft rots, fungal growth, yeasts	Preharvest: Irrigation water, manure or animals. Postharvest: Wash water, poorly cleaned equipment or cross-contamination
Microbial products	Toxins (e.g. patulin, fumonisin), odours, colours	

- The selection of a **cleaning procedure** depends on:
  - the **nature** of the product to be cleaned
  - the **types** and amounts of contaminants likely to be present
  - the **degree** of decontamination that is required

- In general, a **combination** of cleaning procedures is required to remove the different contaminants found on most foods

Wet cleaning

- Wet cleaning is **more effective** and causes **less damage** to foods than dry methods
- It is used, e.g. to remove soil from **root crops** or dust and pesticide residues from **fruits or vegetables**
- Different combinations of **detergents** and **sterilants** allow flexibility to remove different types of contaminants
- **Warm water** improves cleaning efficiency, especially if mineral oil is a contaminant
- However, the use of warm water increases **costs** and accelerates **biochemical** and **microbiological** **spoilage** unless careful control is exercised over washing times and reducing delays before processing

- Wet procedures produce large volumes of **effluent**, often with high concentrations of dissolved and suspended solids

- There is then a requirement to either pay effluent disposal charges or build in-factory water treatment facilities

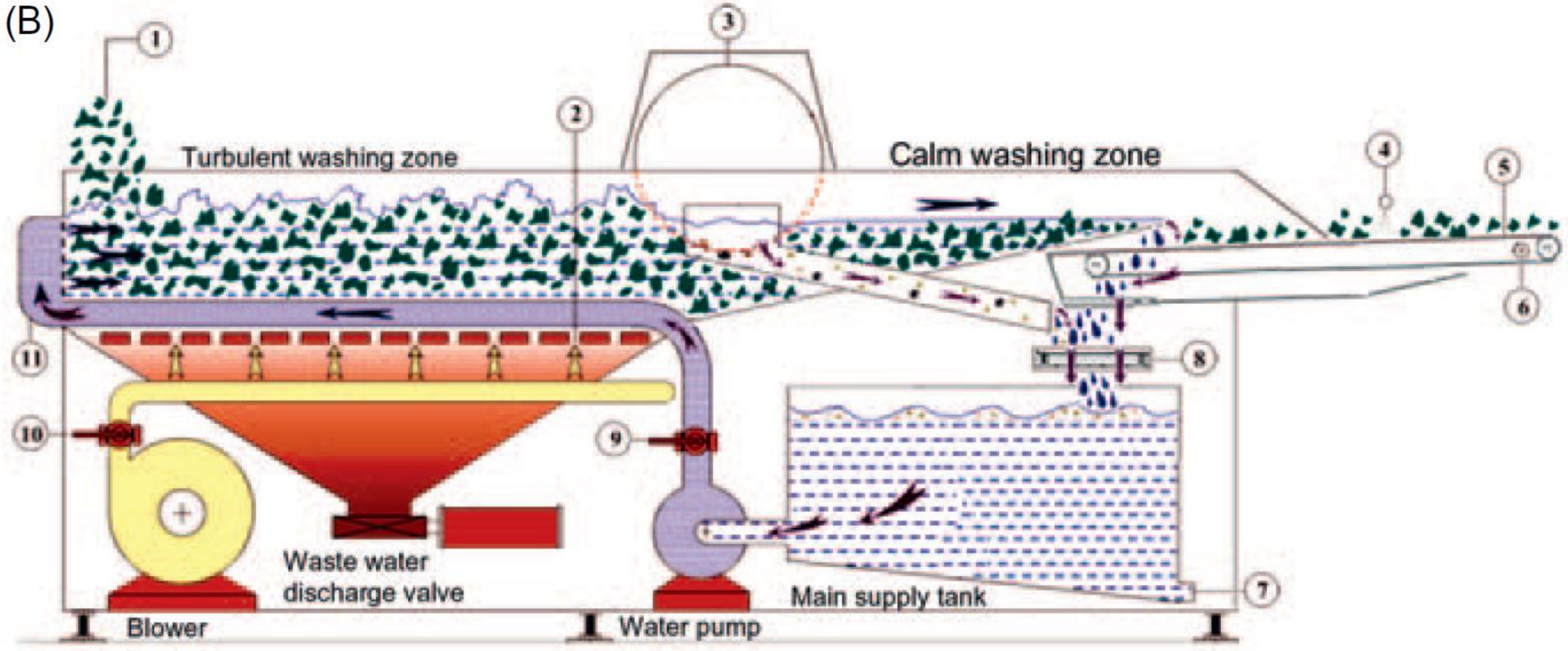
- To reduce costs, water is recirculated, filtered and chlorinated or treated with chlorine dioxide or ozone

- Examples of wet-cleaning equipment include **soaking tanks (**flotation tanks) fitted with stirrers or paddles to agitate the water, spray washers, brush washers, drum or rod washers, ultrasonic cleaners and

- Some designs pump pressurised air into the washwater to create a **turbulent washing zone** that vigorously scrubs foods and increases cleaning efficiency, followed by a **calm zone** that allows fine particles to settle out (Fig. slide137)

- This equipment is suitable for use on **fragile products**, such as strawberries or **asparagus**, or products that can trap dirt internally (e.g. **celery**)

- **Dewatering screens** are used to separate washwater from the clean product



(A) Fruit and vegetable washer with turbulent washing zone

(B) Components and operation

(1) Unwashed product
(2) air injection
(3) optional floating debris removal drum
(4) clean water rinse
(5) discharge belt conveyor
(6) product/debris removal air
(7)supply tank drain
(8) optional water filter
(9) water pump flow control valve
(10) Air supply control valve
(11) pressurised water supply manifold

- **Flotation washing** is based on the differences in **density** in water between foods that float and contaminating soil, stones or rotten crops that **sink**

- **Spray-washing** using **drum** washers or **belt** conveyors is widely used for many types of crops
- Its effectiveness depends on the volume and temperature of the water and time of exposure to the sprays
- Larger food pieces are rotated so that the whole surface is sprayed, and some equipment has brushes or flexible rubber discs that gently clean the food surfaces

Drum washer

Brush washer

Model	GS-120A	Capacity	45L
Inner Tank Size	500 x 300 x 300 mm	Heating Power	1000W (0~~60°C)
Frequency	40KHZ	Ultrasonic Power	720W (10%-100% Adjustable)

Ultrasonic Cleaner

Dry methods of cleaning

- The main types of equipment are **air classifiers**, **magnetic** separators and **electrostatic** separators

- **Sorting equipment**, including **screens**, **shape** sorters and **imaging** machines are also used to remove contaminants

- **Air classifiers** (**aspiration cleaners**) use a fast-moving stream of air to separate contaminants using differences in their **densities** and the **projected areas** of particles

- **Air velocity** required for separation of different particles should be calculated

- Air classifiers are widely used in grain- and legume-**harvesting machines** and for products that have **high mechanical strength** and **low moisture** content (e.g. **nuts**)

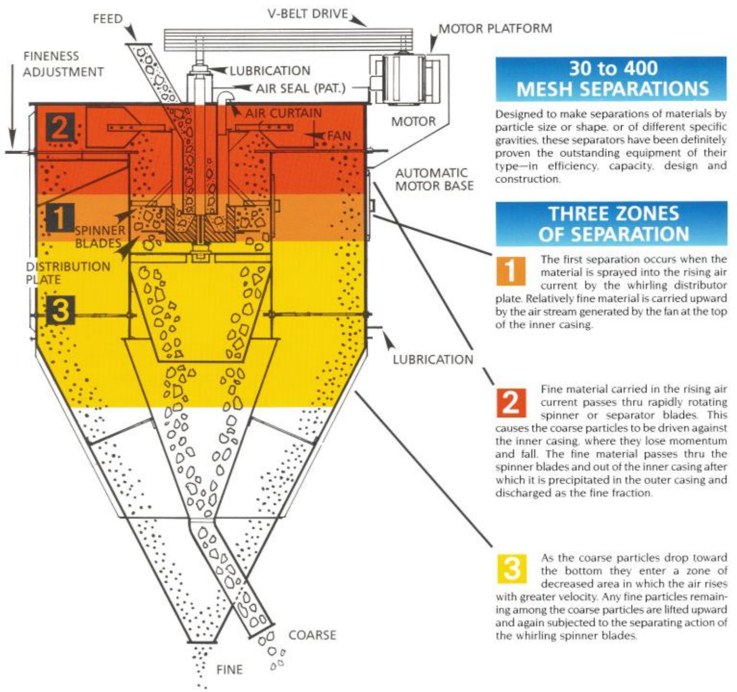
- They remove both **denser** contaminants (e.g. soil, stones) and **less-dense** contaminants (e.g. leaves, stalks and husks)

➢ Compared to wet cleaning:

- The surfaces remain **dry** and the **wastes** may be disposed of **more cheaply** than wet effluents

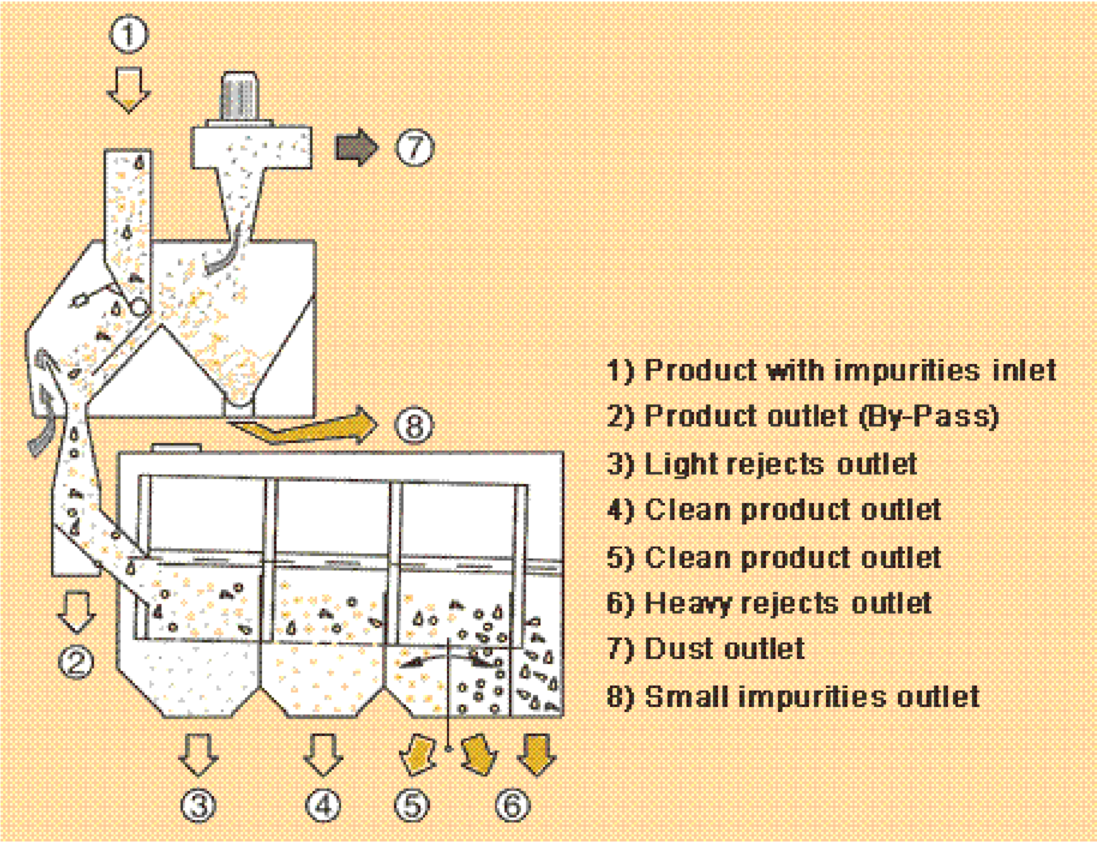
- Plant **cleaning** is simpler and **chemical** and **microbial** deterioration of the food is reduced

❑ However, it may be necessary to prevent or control **dust**, which not only creates a **health** and **explosion** or **fire hazard**, but could also **recontaminate** products



Air classifier

Aspiration Cleaning



Magnetic and electrostatic separators

- Contamination with **metal fragments** or loosened **nuts and bolts** from machinery can occur during processing as a result of wear or damage to equipment, and **metal detection** is therefore an important component of HACCP systems in all food processing plants

- Magnetic cleaning systems for ferrous metals include magnetised **drums** or **conveyor belts**, or magnets located **above conveyors**, in **filters**, or in **pipework**

- **Electromagnets** are preferred to **permanent** magnets because they are easier to clean by switching off the power supply

- Permanent magnets require regular inspection to prevent a build-up of metal that could be lost into the food all at once to cause gross recontamination

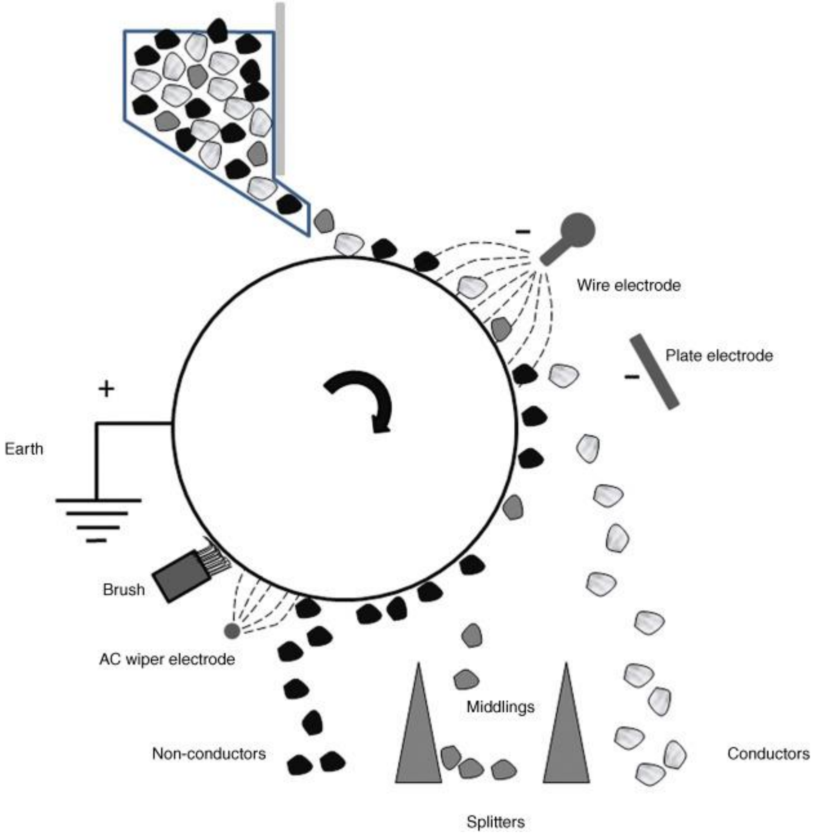
- **Nonferrous metals** are nonmagnetic and require **metal detectors** to protect processing equipment that could be damaged by metal fragments, and **at the end of a processing line** to detect metal contamination in packaged foods as part of a QA/HACCP scheme

- **Electrostatic** cleaning can be used in a limited number of applications where the **surface charge** on a raw material differs from that of **contaminants**

- It has been used, e.g. to remove **weed seeds** that have similar geometry but different surface charge from grains, and for cleaning **tea leaves**

- The food is conveyed on a charged belt and contaminants are attracted to an oppositely charged electrode according to their surface charge

- Electrostatic space charge systems are also used to **clean air** and reduce the transmission of dust and bacteria



Electrostatic Separation

- Electrostatic charging behaviour of food ingredients by charge build-up during blowing of powders through different aluminium charging tubes

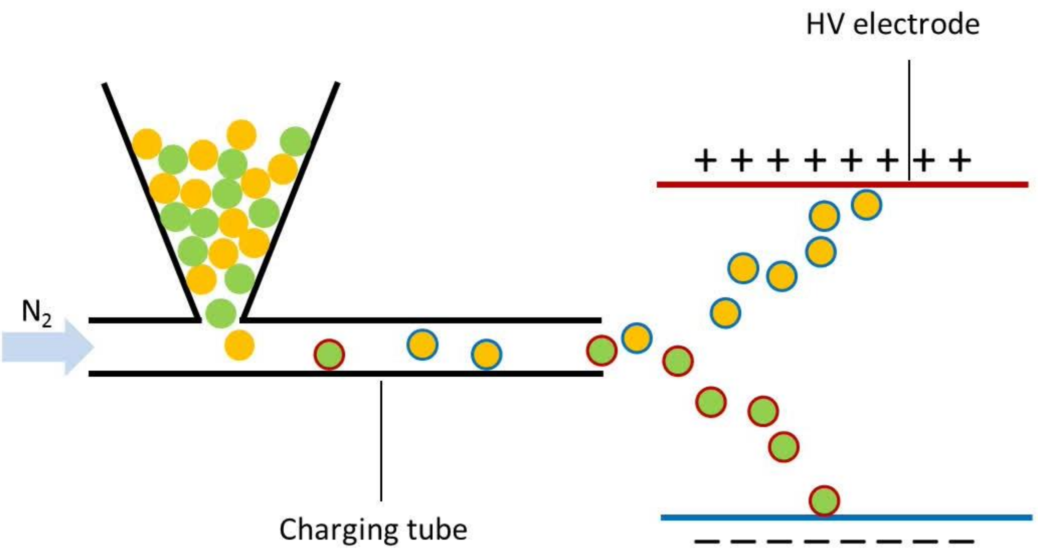


Figure 1. Schematic drawing of a device for electrostatic separation of powders by tribo-electric charging and subsequent separation in an electric field

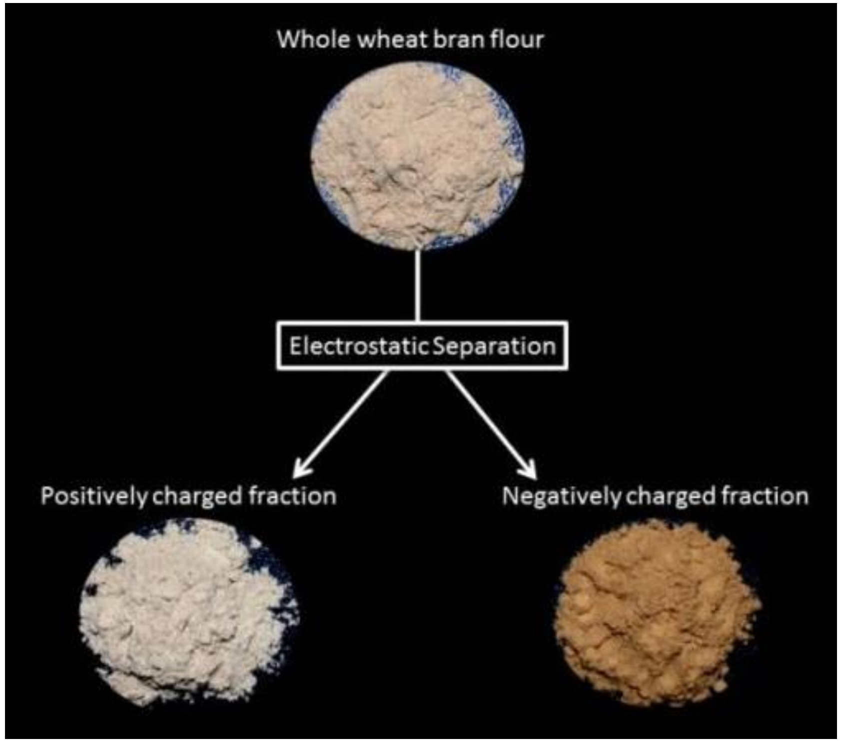


Figure 2. Purified fractions of wheat bran obtained by electrostatic separation

Screens and shape sorters

- Screens in the form of **rotary drums** and **flat-bed designs** (**sieve**) are size separators that are also used to remove contaminants

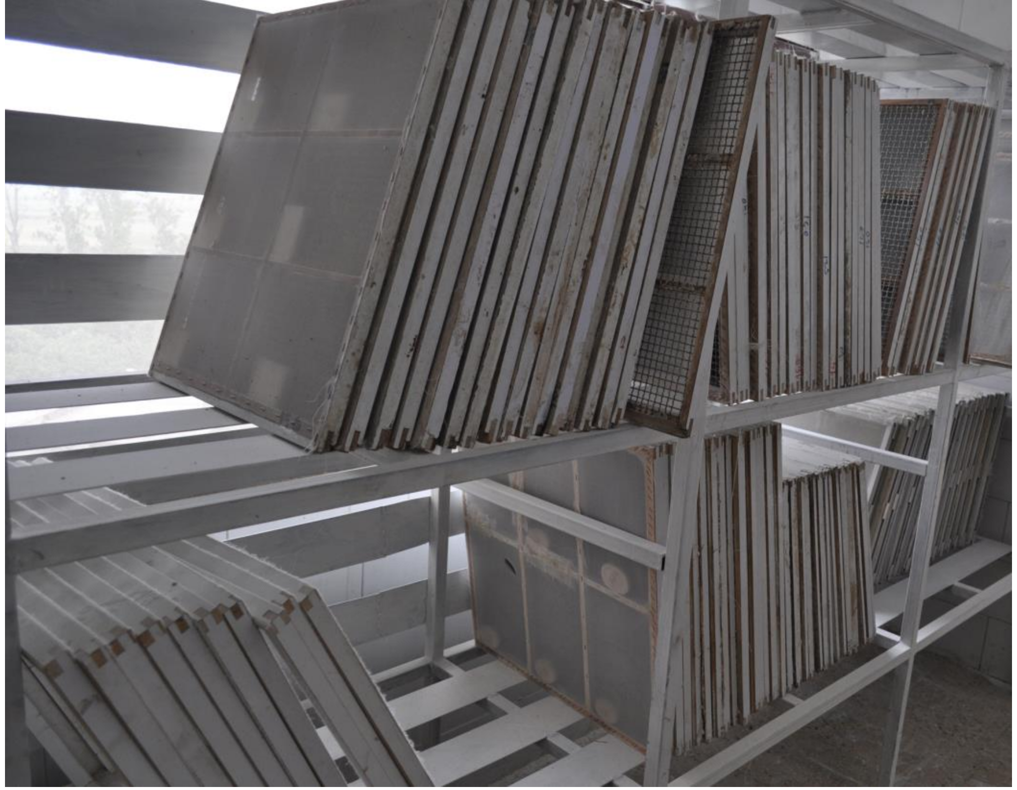
- The removal of **larger contaminants**, such as **leaves and stalks**, from smaller foods is termed **'scalping'**

- The removal of **smaller particles** of sand or dust from larger foods is termed **'sifting'** or **'dedusting'**

- Screening may produce **incomplete separation** of contaminants and is often used as a **preliminary cleaning** stage before other methods

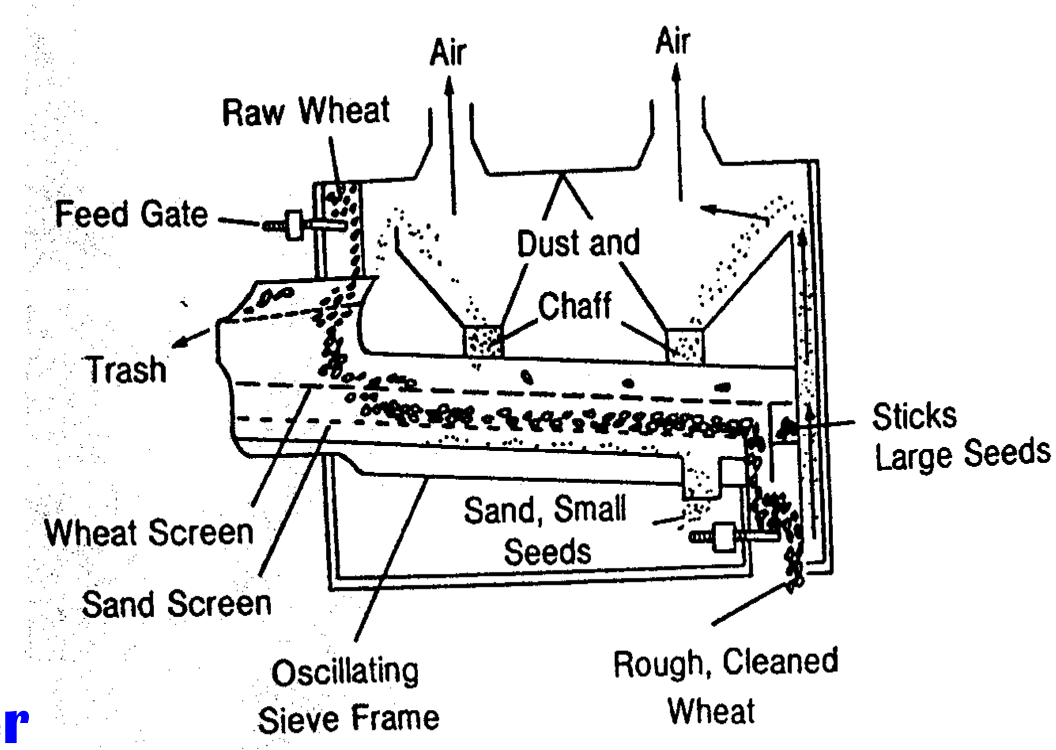
- The efficiency of screens to separate materials may be improved by **vibrating** the screen, or by using **brushes** to remove materials that **block** (or '**blind**') the apertures in the screen

Rotary drum screen



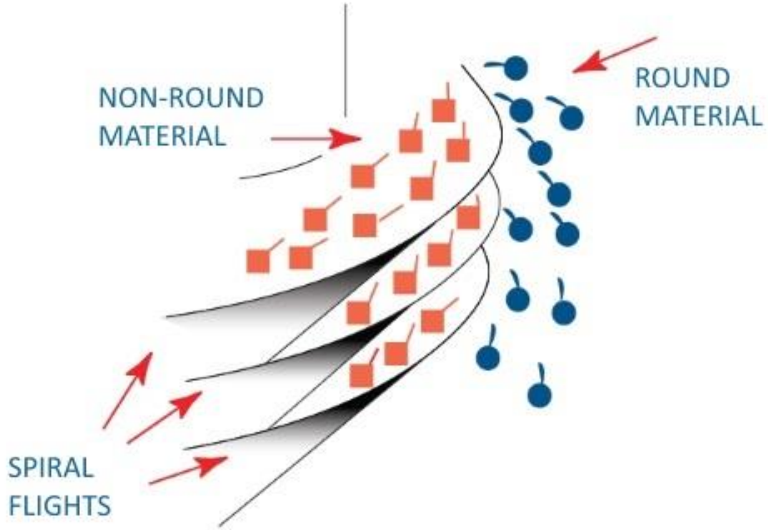
Flat-bed Screens

Grain Cleaner
(flat-bed screen)



- It can be used for most varieties of cereal grains, oilseeds and vegetable or legume seeds
- The **top screen** scalps contaminating chaff, straw and small seeds with the product falling through the screen
- The **bottom** screen (screens) can be configured in either sifting or scalp-sifting operation
- Finally, the product is cleaned using **air aspiration** by a bottom blast fan to remove lightweight materials and dust

Spiral Separator



Spiral separator removes nonround materials (chaff, leaves, seeds, etc.) from round seeds, such as mustard, peas or soybeans **vice versa** (wheat, barley, rice etc.)

Colour and imaging machines

- Many different technologies that are used to **sort and grade** foods are also used to **remove contaminants**, including optical and machine vision systems, magnetic resonance imaging (MRI), ultrasound and X-rays

- Microprocessor-controlled colour sorters compare reflected light to a preset standard and any contaminants that have a **different colour** are automatically rejected

- 'Smart' cameras and the use of **laser light** enable contaminants that have the same colour but a **different shape** to the product to be removed (e.g. green stalks from green beans)

- Machine vision systems are used to check ingredients for contamination by known allergens (e.g. peanuts, soybeans, shellfish, tree nuts, etc.) and also to inspect packages and barcodes to verify that the product is correctly packaged and labelled

- **X-rays** are short-wavelength electromagnetic energy that can penetrate foods to detect **physical defects** or contaminants without damaging the product

- X-ray detectors are able to detect foreign body contaminants, such as metal, glass, rubber, stones, bone fragments, dense plastics and seafood shells in all types of packaged foods, allowing inspection without unpacking the products

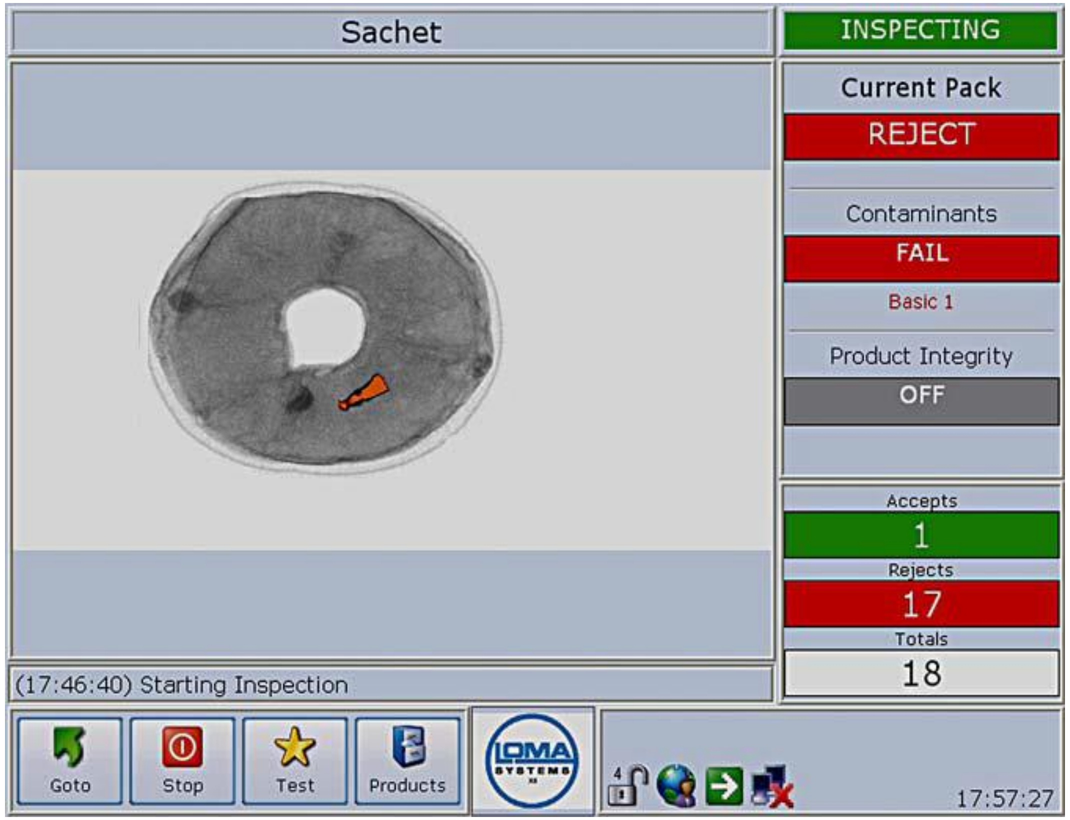
- When they penetrate foods, X-rays lose energy and if they encounter a dense area, such as a metal contaminant, this reduces the energy further

- This is detected by a linear **X-ray sensor**

- The sensor collects and converts the X-ray 'shadow' signals into a greyscale image of the food, with dense contaminants appearing darker in an image displayed on a monitor

- For example, a **fragment of glass** in a pack of **cheese** has a higher absorption than the cheese and generates a shadow that the detector can display and record

- Similarly, it can detect **bones** in **chicken** and **fish** products



X-ray image of contaminant in packaged food

- X-ray detectors also detect missing or underfilled packages and are increasingly used for in-line production control and verification

- There are some contaminants that X-ray inspection systems have difficulty in detecting, including microbial contamination, hair, paper, cardboard, low-density plastics, string, wood and soft tissue such as cartilage

- There are a number of technologies for detecting contaminants based on **electromagnetic** or **imaging techniques** that are under development but not yet used commercially

Table 2.4 Summary of techniques used for foreign body detection

Technique	Wavelength	Food products	Contaminants
Microwave	1–100 mm	Fruits	Fruit pits, stones
Nuclear magnetic resonance	1–10 mm + magnetic field	Fruits and vegetables	Fruit pits, stones
Infrared	700 nm–1 mm	Nuts, fruits, vegetables	Nut shells, stones, pits
Optical	400–700 nm	Fruits and vegetables	Stones, stalks
Ultraviolet	1–400 nm	Meat, fruits, vegetables	Fat, sinews, stones, pits
X-rays	<1 nm	All loose and packaged foods	Stones, dense plastic, metal, glass, rubber, bone
Capacitance	N/A	Products <5 mm thick	–
Magnetic	N/A	Loose and packaged foods	Metals
Ultrasonics	N/A	Potatoes in water	Stones

Sorting and Grading

- The terms ‘**sorting**’ and ‘**grading**’ are often used interchangeably

- But **sorting** means ‘the **separation** of foods into **categories** on the basis of **a** measurable physical property’ (size, shape, weight or colour)

- **Grading** is ‘the **assessment** of **overall quality** of a food using a number of attributes’

- The **distinction** was originally made to characterise simple sorting machines from grading carried out by skilled inspectors who are trained to simultaneously assess a number of variables

- Examples of **grading** include examination of carcasses by **meat inspectors** for:

- Disease
- Fat distribution
- Bone:flesh ratio
- Carcass size and shape

- Other **graded foods** include cheese, coffee and tea, which are assessed by **specialist tasters** for flavour, aroma, colour, etc

- Eggs are visually inspected by operators over tungsten lights ('**candling**') to assess up to 20 factors, to remove those that are **fertilised** or **malformed** or those that contain **blood spots** or **rot**

- In some cases the grade of food is determined from the results of **laboratory analyses:**

  - For example, **wheat** is assessed for **protein** content, **colour**, **moisture** content and presence of **insects**

- The **distinction** between **sorting** and **grading** has steadily broken down with the development of sophisticated **machine vision systems** that can simultaneously assess a number of **attributes**

- **For example:**
  - In **chicken meat** inspection, machine vision systems can assess bruising, skin colour and damage

  - **Fruits** grading machines can simultaneously measure **100** characteristics including colour, weight, diameter, sugar content, ripeness, blemishes, or internal characteristics such as 'water core'

- The **change** from trained **inspectors** to **machine-based systems** is driven by a number of factors:

    - Pressures from large retailers for uniform products, especially fruits and vegetables
    - Increased labour costs for inspectors (machine vision systems perform significantly better with lower costs)
    - Product **tracking** and traceability requirements

- Like **cleaning**, sorting and grading should be employed **as early as possible** in a process to ensure a uniform product for subsequent processing and to prevent expenditure on materials that are subsequently discarded as substandard

Shape and size sorting

- The **shape** of some foods is important in determining their suitability for **processing** or their **retail** value in the fresh market sector

- For example,
    - for economical **peeling**, **potatoes** should have a uniform **oval or round shape** without **protuberances**
    - **Cucumbers** and **gherkins** are more easily packaged if they are **straight**
    - Foods with a characteristic shape (e.g. **pears**) have a higher retail value if the shape is **uniform**

- A **uniform size** is also important and retailers usually specify the size range of fresh products
- Meeting these specifications has a significant effect on the **price** received and **profitability** of a grower’s operations
- In the **processing** sector, the **size** of individual pieces of food is particularly important when a product is heated, dried or cooled, because it in part determines the **rate of heat or mass transfer**

  \- any significant variation in size causes **overprocessing** or **underprocessing**

- The correct **size distribution** of small particulate foods such as **sugar** or **powdered** ingredients (e.g. **starch**, colourants, thickeners, etc.) is also important to achieve uniform products in **mixing and blending** operations

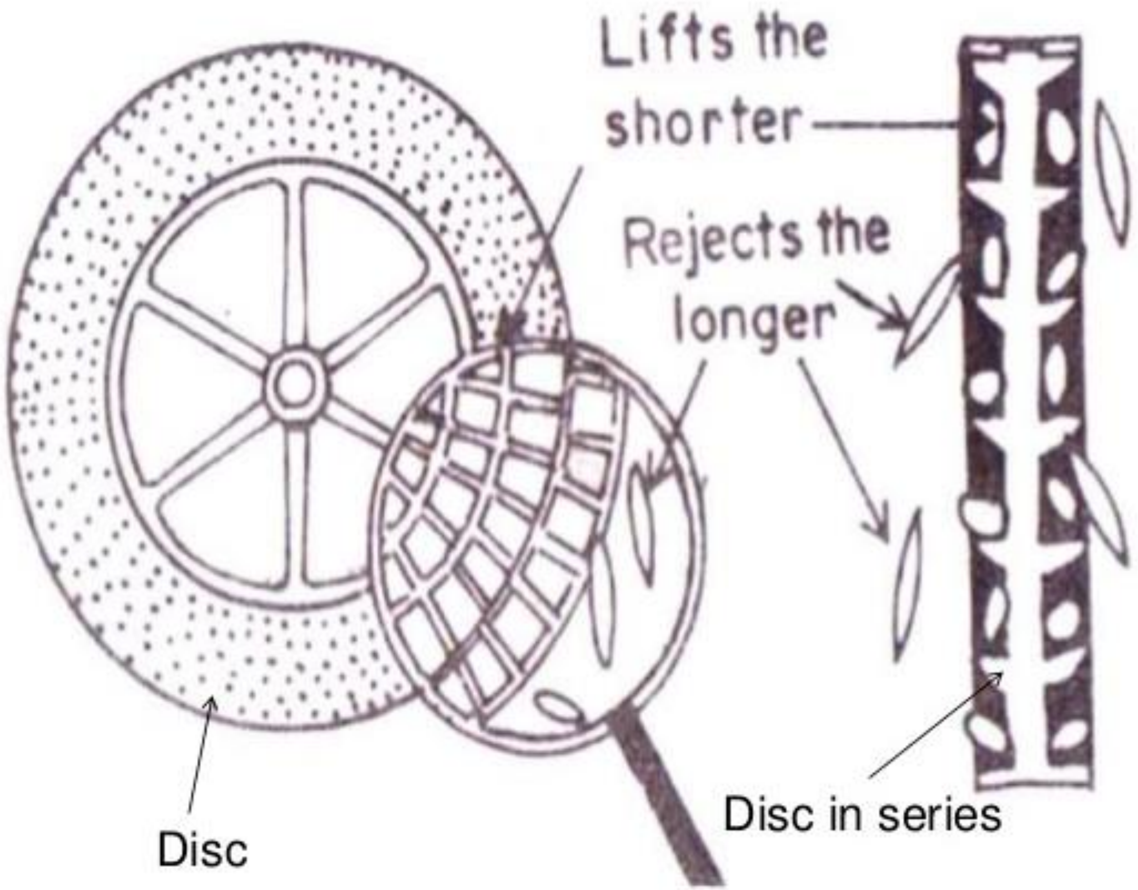
- **Size sorting** (termed ‘sieving’ or ‘screening’) is the separation of solids into two or more **fractions** on the basis of differences in size
- **Shape sorting** is useful where foods contain contaminants that have similar size and weight

- Examples of equipment used for **shape sorting** include:
  - the **disc sorter (disc separator)**
  - and various types of **screens**
  - **Machine vision systems** can also be used to sort foods on the basis of their shape

- The **disc sorter** has vertical discs that have indentations precisely machined to match the shape of a **specific grain**

- The discs are partly embedded in a mass of grain and selectively **lift** the required grains, leaving **weed seeds** and other materials behind

- **Different discs** can be fitted for each of the common food grains



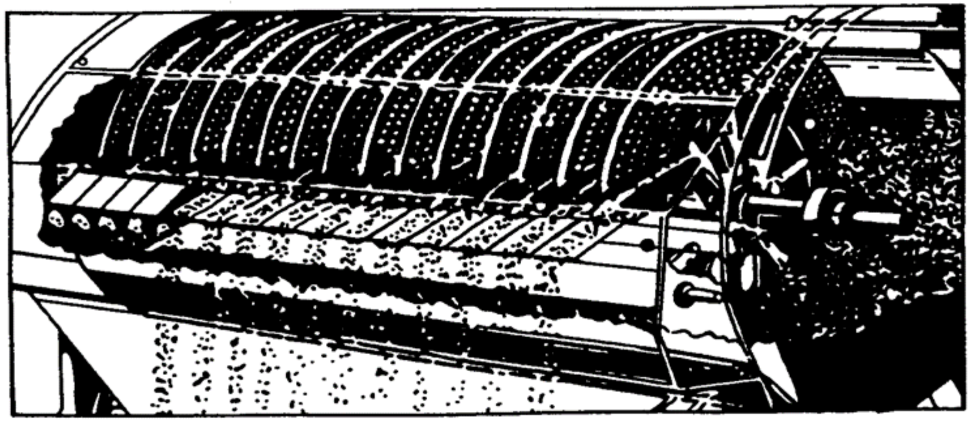


Fig. 8. Disc separator.

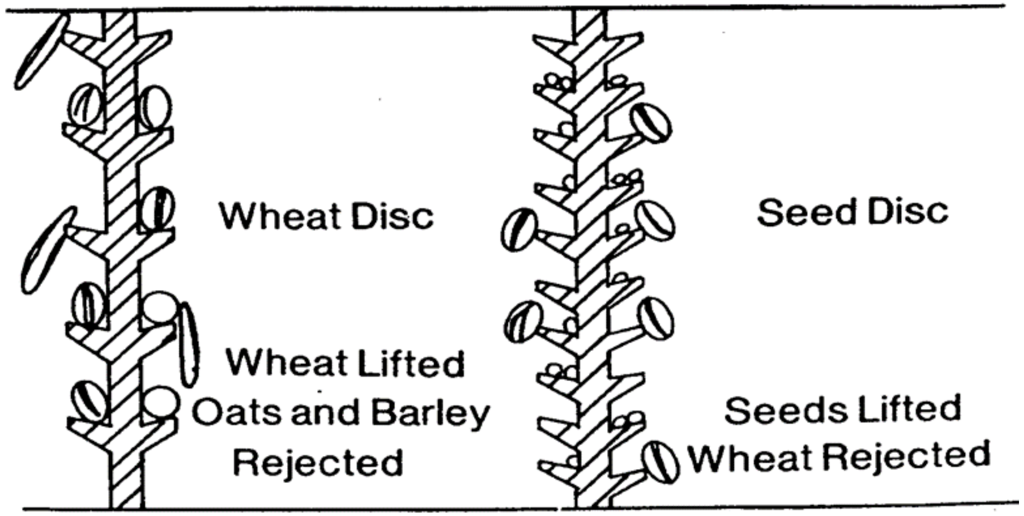


Fig. 9. Disc separator: cross sections of wheat disc and seed disc.

Disc Separator

- **Screens** with either fixed or variable apertures are used for size or shape sorting

- The screen may be **stationary** or, more commonly, **rotating** or **vibrating**.
- Fixed aperture screens include the flat-bed screen (or sieve) and the **drum** screen (rotary screen)(**Trommel**)

- The **multideck** flat-bed screen is similar to the equipment used for **grain cleaner** has a number of horizontal mesh screens, which have aperture sizes from 20 µm to 125 mm (or upto 1000µ), stacked inside a **vibrating frame**

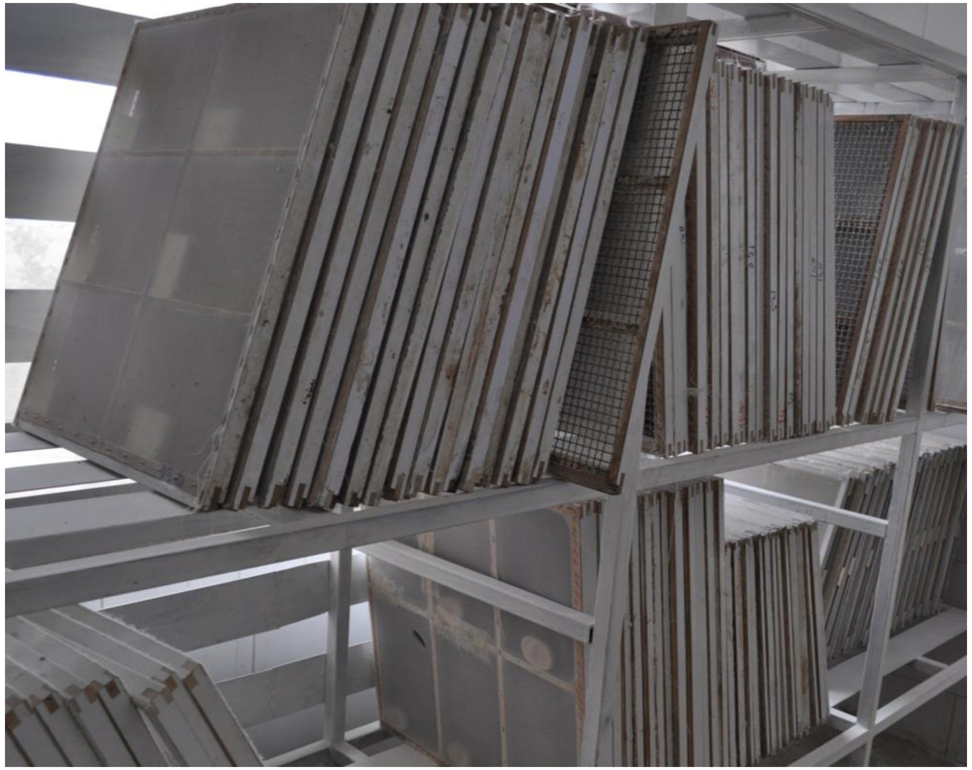
- These types of screen are widely used for sorting dry **particulate foods** (e.g. flour, sugar and spices)

- The **main problems** arise due to **high humidity**, which causes small particles to stick to the screen or to **agglomerate** and form larger particles that are then discharged as oversize

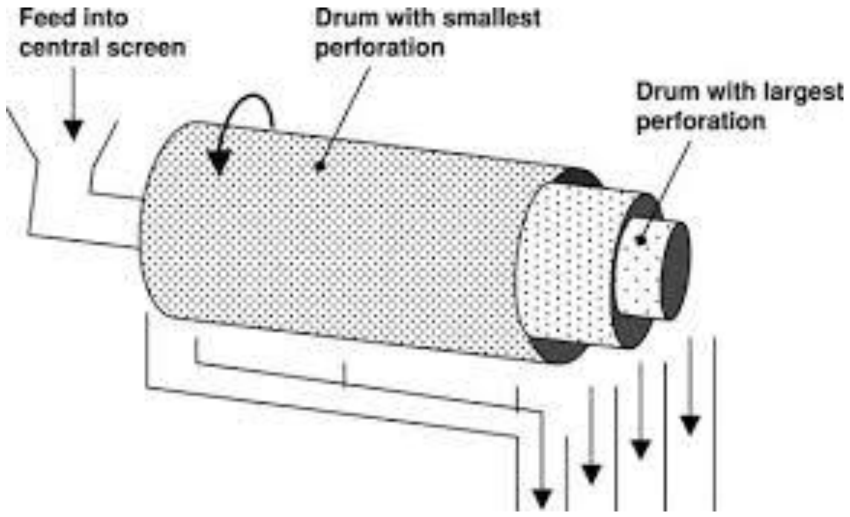
- Particles may also cause **blinding** of the screen, particularly if the particle size is close to that of the screen aperture

- Where vibration alone is insufficient to adequately separate particles, a **gyratory** movement is used to spread the food over the entire sieve area, and a vertical **jolting** action breaks up agglomerates and **dislodges** particles that block sieve apertures

multideck flat-bed screens



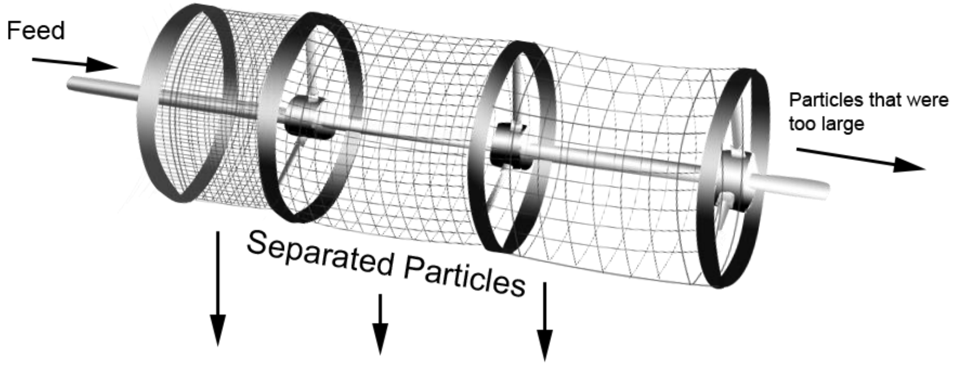
- **Drum screens** are almost horizontal, perforated metal or mesh cylinders that may be **concentric** (one inside another), **parallel** (foods leave one screen and enter the next) or **series** (a single drum constructed from sections with different-sized apertures)



- Some designs may be fitted with **internal brushes** to reduce blinding

- All types have a **higher capacity** than flat-bed screens

- They are used for sorting **small particulate foods** (e.g. nuts, peas or beans) or **root crops** that have sufficient mechanical strength to withstand the tumbling action inside the screen



- In **expanding belt or roller sorters**, foods pass along the machine until the space between the rollers or belts is sufficiently large for them to pass through

- The belts or rollers may be driven at different speeds to rotate the food and thus to align it to present the smallest dimension to the aperture (e.g. the diameter along the core of a fruit)

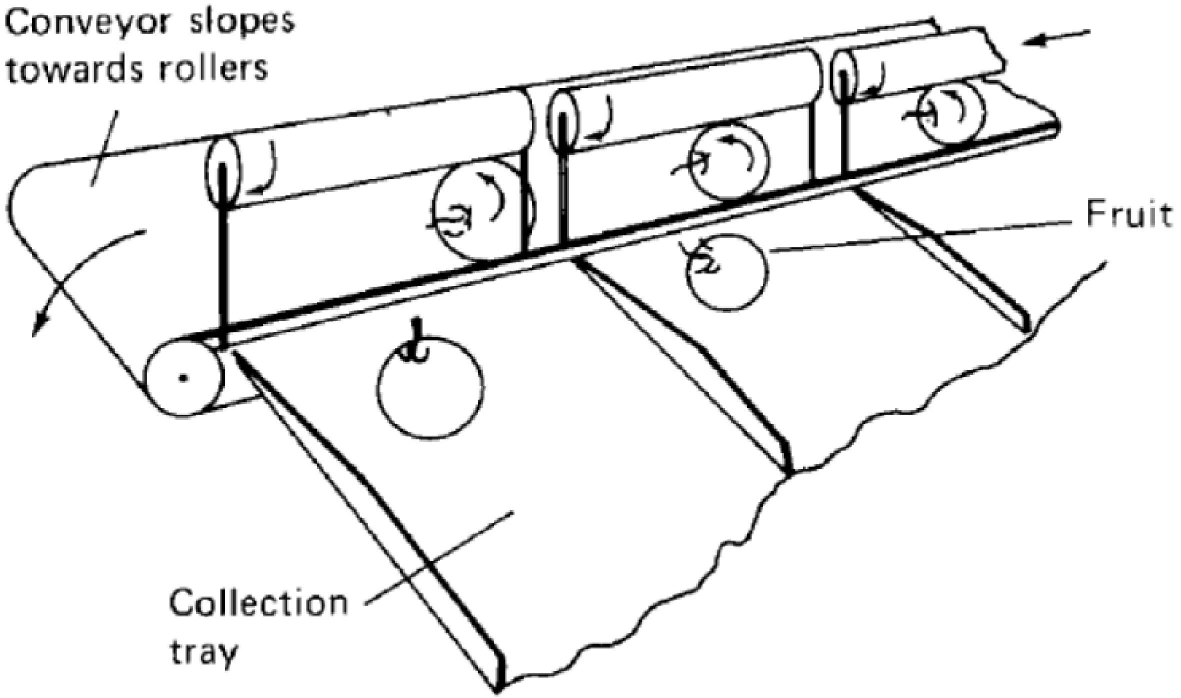
- Stepwise increases in aperture are produced by adjusting the gap between driven rollers and an inclined conveyor belt

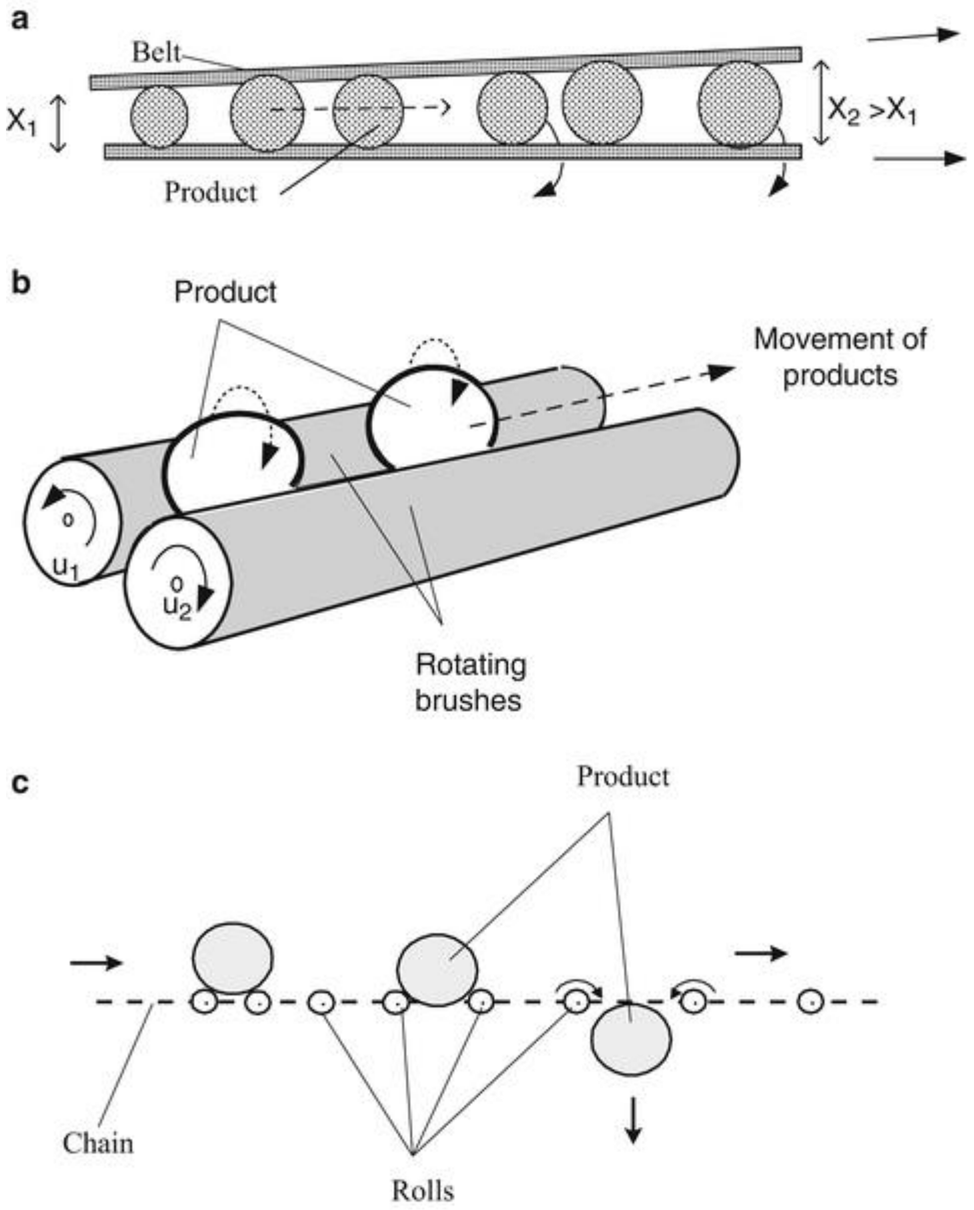
Weight sorting

- Weight sorting is **more accurate** than other methods and is therefore used for more **valuable foods** (e.g. eggs, cut meats and in industrialised countries, some tropical fruits)

- **Eggs** are sorted at up to 190,000 h^{-1} into **five to nine** categories

- They are first graded by '**candling**' and then pass to a **weight sorter**





Expanding belt or roller sorters

- Eggs are transported to a series of **digital scales** incorporated into a conveyor, which weigh each egg to a tolerance 0.1 g (with automatic recalibration between each egg weighing)
- The conveyor operates alternatively and while stationary, tipping or compressed air mechanisms remove heavier eggs, which are discharged into padded chutes
- Lighter eggs are replaced on the conveyor to travel to the next weighing scale where the procedure is repeated
- Equipment is computer-controlled and intelligent software, linked to a **colour digital camera**, identifies **dirt** on eggs as small as 1 mm^2, detects **cracks** and identifies tiny **blood spots** inside eggs
- Cracked or blood eggs are automatically **ejected** and dirty eggs are returned to the **egg-washer**
- The grader can also provide management data on quantities of graded eggs and their size distributions

Egg grader

https://www.youtube.com/watch?v=xINOGz6KdyE&feature=youtu.be

https://www.youtube.com/watch?v=HpY-Xlvibpo

- **Aspiration** and **flotation** sorting equipment exploits differences in food **density** to sort foods and is similar in design and operation to machines used for aspiration and flotation **cleaning**

- **Grains, nuts and pulses** can be sorted by **aspiration**

- **Vegetables** can be sorted by flotation in brine (specific gravity = 1.1162 - 1.1362)

  - For example, the **density** of **peas** correlates with their **tenderness and sweetness**: denser, starchy, overmature pieces **sink** and are separated from the required product, which floats in the **brine**

  - The density of **potatoes** directly correlates with solids content, which determines their suitability for **chips** manufacture

Colour and machine vision sorting and grading systems

- There are **two types** of machine colour sorter/grader:

  1) Those that use **photodetectors** to sort small, particulate foods

  2) Those that use '**smart**' cameras to sort or grade **larger foods**, such as **bakery products** and **fresh fruits and vegetables**

1) Photodetectors

- Small particulate foods are sorted at high rates (up to 25 t / h) using microprocessor-controlled **colour sorting** equipment **(Fig)**

- Particles are fed into multiple chutes in **single layers**, where they are illuminated by **laser** or **LED light**

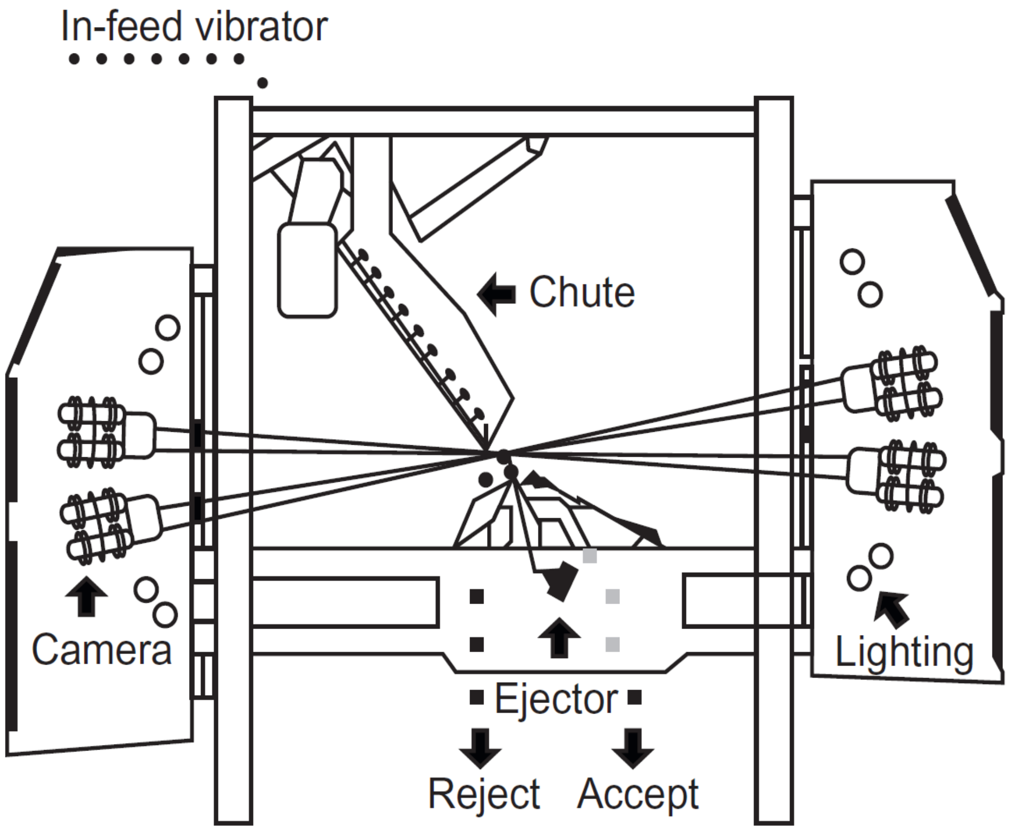
- The **type** and **intensity** of the light, including **infrared** and **ultraviolet** or **combinations** of these with visible light, are selected to **differentiate** the colour of the product from defective pieces or contaminants

- To maximise the differentiation, the wavelengths that produce unique **'signatures'** for each product are identified

- Sensors measure the **reflected colour** of each piece and the image processing system compares the data with preset standards for the selected food Defective

- Pieces are separated by a short blast of **compressed air**

(A)



(B)

Colour sorting: (A) operation of a microprocessor-controlled colour sorter and (B) optical sorter

- ❑ Typical applications include peanuts, rice, diced carrot, maize kernels, cereals, sugar confectionery, snackfoods and small fruits

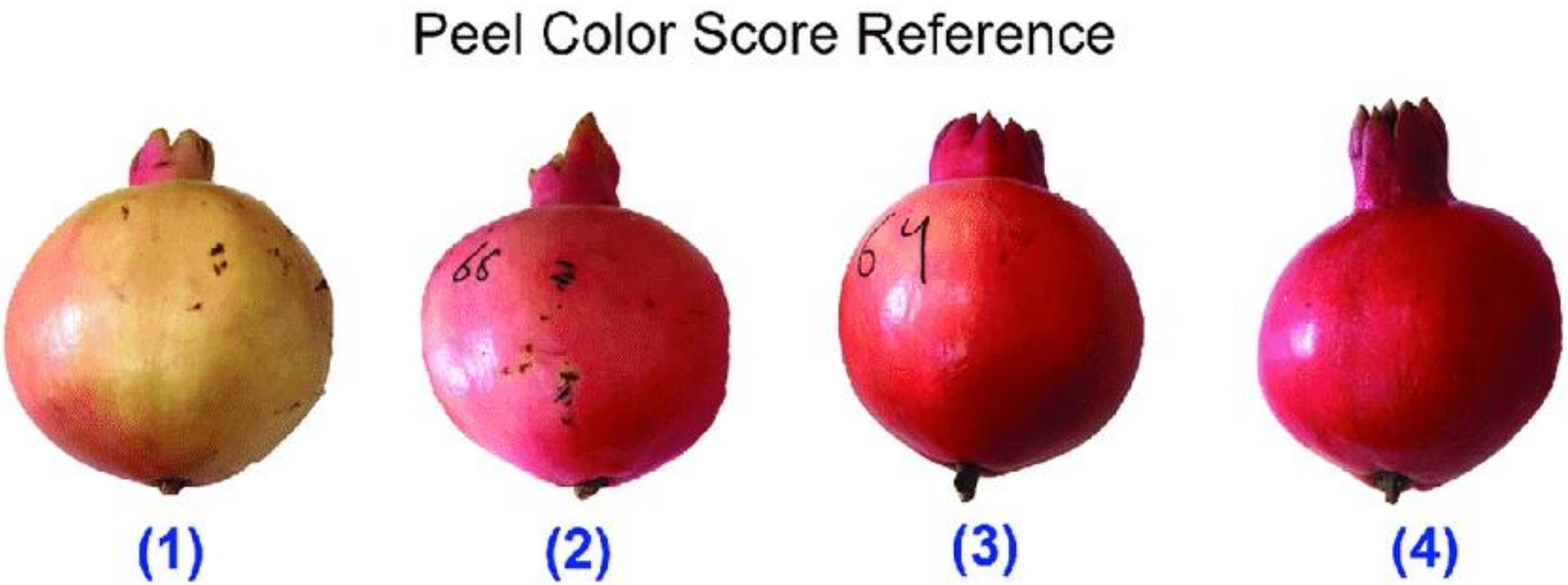
2) High-resolution **digital cameras** can detect **millions of colours**, with resolution sensors capable of detecting defects as small as 1 mm

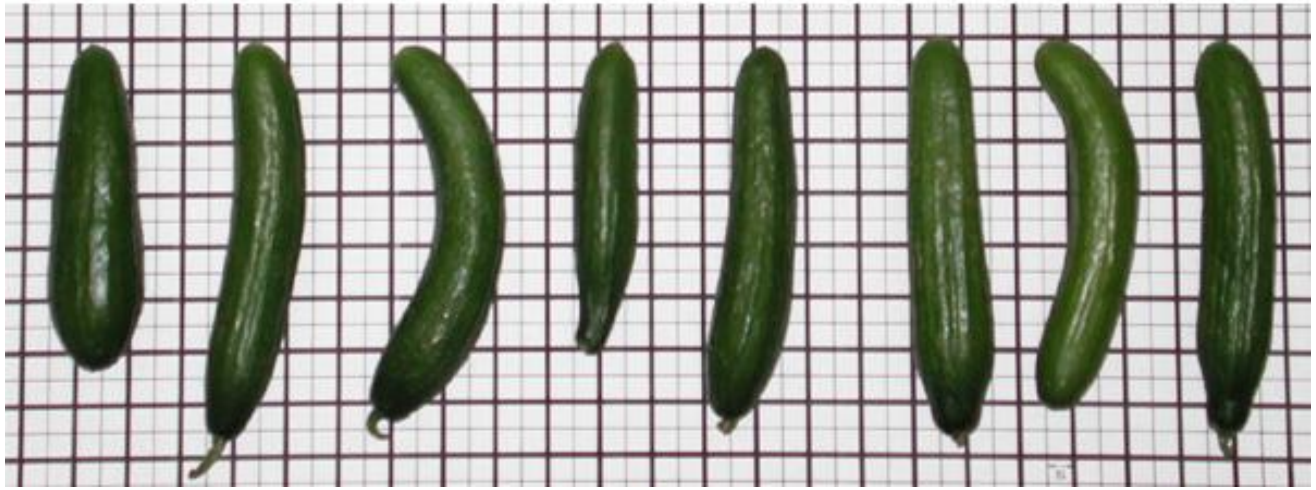
- Object-based recognition software enables the grader to **analyse attributes** such as size, shape, symmetry, length and curvature as well as colour, colour distribution and surface properties
- The equipment can be '**trained**' by operators to evaluate defects, by simply '**showing**' examples to the system
- It will then **grade** products into **different quality classes** according to the type of defects that are detected
- The grader can remove individual food pieces that are under- or over-ripe, or pieces that are damaged by insects or infection, or are misshapen **(Fig)**
- Colour/weight/diameter graders are used for grading **fragile fruits** such as peaches, avocados, mangoes and kiwis, and vegetables including bell peppers and tomatoes
- Fruits or vegetables in multiple rows are placed in **individual cups** or pockets and pass under cameras that capture images of the entire surface of the product as they are rotated
- The images can be used for **sorting** based on colour ratios, colour-intensity histograms or minimum/maximum defined areas of a particular colour

(a)

(b)

(c)





Cucumber curvature

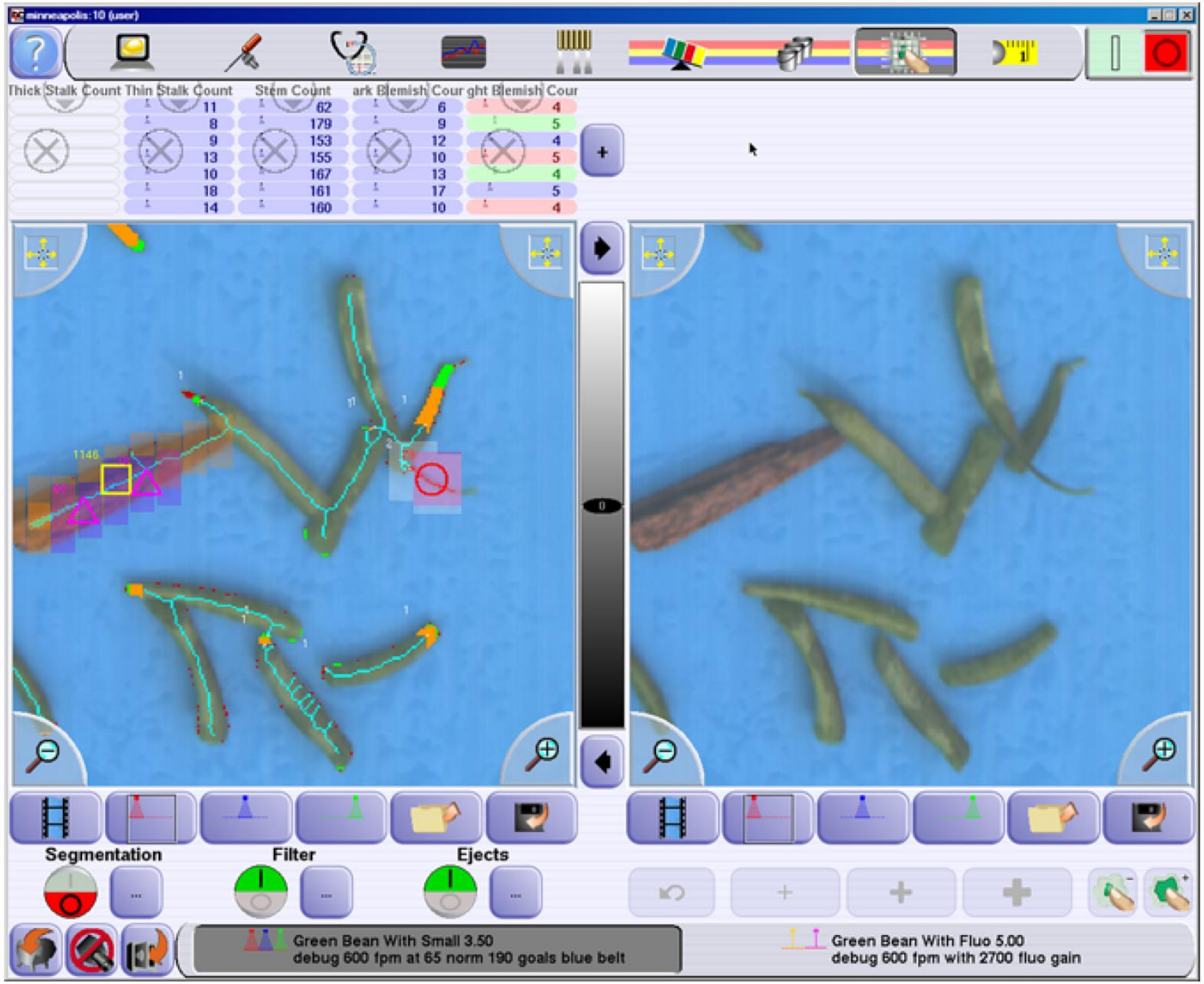


Figure 2.12 Grading software recognises beans, stems and foreign materials.

- In other methods, **near infrared (NIR)** light is used to measure **sugar content** (Brix) and other quality characteristics of whole fruits or vegetables, such as acidity, aroma, ripeness, maturity or internal faults such as water core

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- **Laser light** may be used to detect same-colour **insects** or **animal parts**, based on differences in their **structural properties**

- **Fluorescence-sensing laser** sorters can detect and analyse the amount of fluorescent light emitted by **chlorophyll** in vegetables, or green discolouration on potatoes

- The chlorophyll appears white on the display whereas everything else, including brown spots on the vegetables and same-colour insects, **do not transform the laser energy** and appear black

- Machines that have **X-ray-based vision** systems can detect internal **flaws** or physiological conditions that are not detectable by scanning the surface of the product

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- An '**acoustic firmness sensor**' enables on-line, nondestructive measurement of firmness and related characteristics of whole fruits

- The grader gently taps the product and 'listens' to the vibration pattern

- The acoustic signal (or 'resonance attenuated vibration') is characteristic of the overall firmness, juice content, freshness and the internal structure of the product, including, e.g. tissue breakdown or dehydration
- The signal is analysed to create a '**firmness index**', which allows the ripeness and other quality aspects to be determined