



## Types of Centrifuges and their Applications in Modern Agriculture

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Centrifugation is an essential separation technique extensively used in agricultural sciences, biotechnology, food processing, environmental studies and molecular biology laboratories. The process utilizes centrifugal force to separate particles based on differences in density, size and molecular weight. Various types of centrifuges are designed to meet specific laboratory and industrial requirements, ranging from low-speed clinical centrifuges to highly advanced ultracentrifuges. In agriculture, centrifuges play a significant role in seed technology, soil science, dairy processing, plant biotechnology, microbial studies, pesticide residue analysis and biofertilizer production. The efficiency and accuracy of centrifugation depend upon factors such as rotor design, speed, temperature control and sample characteristics. This article provides a comprehensive overview of the principle of centrifugation, classification of centrifuges, operational features and their important applications in modern agricultural research and allied industries.

### Introduction

The ability to separate and purify biological and chemical components is fundamental to modern agricultural research, biotechnology and food processing industries. Among the various separation techniques available, centrifugation has emerged as one of the most efficient and widely used methods for isolating particles based on differences in their size, density and molecular characteristics. By generating centrifugal force through rapid rotation, centrifuges enable the separation of complex mixtures into their individual components with high precision and speed. Over the years, centrifugation has become an indispensable tool in agricultural laboratories, research institutions and industrial processing units. Its applications extend across diverse fields including soil science, seed technology, plant breeding, molecular biology, plant pathology, microbiology, dairy technology and environmental studies. The technique is routinely employed for the extraction of DNA and RNA, purification of proteins and enzymes, isolation of microorganisms, seed quality assessment and processing of agricultural products. Advancements in centrifuge design and automation have led to the development of specialized instruments capable of handling a wide range of sample volumes and separation requirements. From compact microcentrifuges used in molecular research to sophisticated ultracentrifuges employed for macromolecular analysis, each type serves a specific purpose in scientific investigation and industrial applications. Understanding the principles, types and applications of centrifugation is therefore essential for researchers, students and professionals involved in modern agricultural sciences. This article highlights the working principle of centrifugation, major types of centrifuges and their important applications in agriculture and allied sectors.

## Principle of Centrifugation

Centrifugation works on the principle of sedimentation in which particles are separated from the sample according to their density under the influence of centrifugal force generated by rapid rotation.

The centrifugal force can be expressed as,

$$RCF = 1.118 \times 10^{-5} \times r \times N^2$$

In which,

**RCF** = Relative Centrifugal Force ( $\times g$ )

**r** = Radius of rotation (cm)

**N** = Rotational Speed (rpm)

Heavier particles tend to sediment faster, while lighter particles remain suspended for a longer duration.

## Functions of Centrifuge

1. To distinguish between cellular and subcellular elements
2. To distinguish between different types of cells.
3. Eliminating suspended particles, such as cells, from their surroundings on either a batch or a basis of continual flow.
4. To separate viruses and macromolecules, such as proteins, lipids, DNA and RNA, or to determine the physical characteristics of these particles based on how they behave during centrifugation.
5. To investigate how centrifugal pressures affect growing embryos, cells and protozoa.

## Types of Centrifuges

### 1. Microfuges

- Tabletop versions of micro centrifuges use light, small-volume rotors that which are capable of very quick acceleration up to 17,000 RPM. They are tiny, lightweight centrifuges that centrifuges samples between 0.2 and 2.0 ml for brief periods of time.
- Because of their small size, they are easily transportable and can be used in a cold room if needed. It can be ambient or refrigerated (depending on model). DNA extraction, PCR preparation, Molecular marker analysis and plant tissue culture studies generally uses the micro centrifuge. High-speed micro centrifuges can generate 2000 to 20,000 RCF or can rotate at up to 6,000 to 15,000 RPM.



Fig.1. Microfuge

### 2. Low-speed centrifuges

- Low-speed centrifuges are widely used in agricultural laboratories for the separation of larger particles and cellular materials. They play an important role in seed testing by separating damaged, immature and non-viable seeds from healthy seeds based on density differences. In soil science, these centrifuges are employed for the separation of soil particles, clay fractions and suspended materials during soil analysis. They are also used for harvesting plant cells from tissue culture media and concentrating microbial cells from liquid cultures for



Fig.2. Low-speed centrifuge

further studies related to biofertilizers, plant growth-promoting microorganisms and disease diagnosis.

- Density gradients for cell purification can also be run in these centrifuges. Swinging-bucket rotors are often employed due to considerable sample size flexibility of adaptors.
- These centrifuges have maximum rotor speeds of less than 10,000 RPM and range in size from tiny benchtop units to massive floor-standing models.

### 3. High-speed centrifuges

- High-speed centrifuges are frequently used to isolation of chloroplast, mitochondria, fungal spores and bacterial cells.
- The majority of basic pelleting tasks are completed in fixed angle rotors.
- Swinging bucket rotors or fixed-angle rotors in the case of Percoll gradients, can do some density-gradient operations for cell and organelle purification.
- High-speed or super-speed centrifuges can handle larger sample amounts from a few tens of millilitres to several litres.
- Greater angular velocities (~ 30,000 RPM) can also be attained by larger centrifuges.
- The rotors may come with several adaptors to accommodate various test tube, bottle or microtiter plate sizes.



**Fig.3. High-speed centrifuge**

### 4. Ultra centrifuges

- Unlike micro centrifuges and super centrifuges, which can only separate particles in batches (limited volumes of samples must be handled manually in test tubes or bottles), ultracentrifuges can separate molecules in batch or continuous flow systems.
- Ultracentrifuges can spin at up to 1,50,000 revolutions per minute or  $15,00,000 \times g$  RCF.
- Fixed-angle rotors are used to collect endosomes, ribosomes, ribosomal subunits, plasmids, DNA, RNA and proteins.
- They can also isolate much smaller particles than micro centrifuges or high-speed centrifuges.
- Separating different lipoprotein fractions from plasma, deprotonating physiological fluids for amino acid measurement and separating macromolecules/ligand binding kinetic studies- ultracentrifugation is used for all of them.
- They are the most popular centrifuge for density-gradient purification of all particles, with the exception of cells.



**Fig.4. Ultracentrifuge**

Although swinging buckets have historically been used for this, fixed-angle rotors and vertical rotors are also used, particularly for self-generated gradients and can significantly increase separation efficiency.

**Table 1: Comparison between all four types of centrifuges**

Sr No	Parameter	Low-Speed Centrifuge	Microcentrifuge	High-Speed Centrifuge	Ultracentrifuge
1	<b>Typical Speed (RPM)</b>	500 - 6,000	10,000 - 18,000	10,000 - 30,000	20,000 - 150,000
2	<b>Typical RCF (×g)</b>	500 - 6,000	10,000 - 30,000	10,000 - 65,000	50,000 - 1,500,000

3	<b>Sample Volume</b>	5 mL - 1 L or more	0.2 - 2.0 mL	1.5 - 500 mL	0.1 - 250 mL
4	<b>Temp. Control</b>	Usually, non-refrigerated	Usually, non-refrigerated (some refrigerated models available)	Often refrigerated	Always refrigerated and vacuum operated
5	<b>Rotor Types</b>	Swinging-bucket, fixed-angle	Fixed-angle	Fixed-angle, swinging-bucket	Fixed-angle, swinging-bucket, vertical
6	<b>Main Separation Basis</b>	Large particles and cells	Small biological samples	Cell organelles, precipitates, microorganisms	Macromolecules and nanoparticles
7	<b>Typical Applications</b>	Blood separation, soil suspensions, seed testing	DNA/RNA extraction, PCR preparation, protein pelleting	Organelle isolation, microbial harvesting, protein precipitation	Virus purification, ribosome isolation, exosome separation, molecular biology research
8	<b>Common Tube Size</b>	5 - 1000 mL	0.2 - 2.0 mL	1.5 - 500 mL	0.1 - 250 mL
9	<b>Vacuum System Required</b>	No	No	No	Yes
10	<b>Relative Cost</b>	Low	Low to Moderate	High	Very High
11	<b>Laboratory Level</b>	Clinical, teaching, agricultural labs	Molecular biology labs	Advanced research labs	Specialized research facilities

## Applications of centrifuge in agriculture

### 1. Soil science and soil analysis

Centrifugation is widely used in soil science laboratories for the separation of soil particles based on their size and density. It assists in soil texture analysis, isolation of clay and colloidal fractions, determination of soil moisture characteristics and extraction of nutrients for chemical analysis. The technique helps researchers understand soil properties that influence crop growth and nutrient availability.

### 2. Seed technology and seed quality assessment

In seed technology, centrifuges are employed for seed cleaning, grading and quality evaluation. The technique helps separate immature, damaged and low-density seeds from healthy seeds, thereby improving seed quality and germination potential. Centrifugation also aids in the detection of seed-borne pathogens and supports seed certification programs.

### 3. Plant Biotechnology and Molecular Biology

Centrifugation plays a crucial role in plant biotechnology and molecular research. Microcentrifuges and refrigerated centrifuges are routinely used for DNA and RNA extraction, protein purification, enzyme isolation and preparation of samples for polymerase chain reaction (PCR) and molecular marker analysis. The technique is also valuable for the isolation of chloroplasts, mitochondria and other cellular components used in advanced plant research.

### 4. Plant pathology and microbiology

In plant pathology and microbiology laboratories, centrifuges are used for the isolation, concentration and purification of fungal spores, bacterial cells, viruses and microbial cultures. These applications support disease diagnosis, pathogen identification and the production of microbial inoculants and biofertilizers. The technique enables rapid processing of samples and improves the accuracy of laboratory investigations.

### 5. Dairy and food processing industries

Agricultural processing industries extensively utilize centrifugation for product purification and quality enhancement. In dairy technology, centrifuges are used to separate cream from milk and remove microbial contaminants. In food processing industries, they assist in fruit juice clarification, starch recovery, edible oil purification, sugar processing and fermentation-based production systems.

### 6. Environmental monitoring and waste management

Centrifugation contributes significantly to environmentally sustainable agriculture through its applications in wastewater treatment, sludge dewatering, organic waste recycling and biogas slurry management. Continuous-flow and decanter centrifuges improve the efficiency of waste processing and resource recovery while minimizing environmental pollution.

### 7. Agricultural biotechnology and crop improvement

Advanced high-speed centrifuges and ultracentrifuges are indispensable tools in modern agricultural biotechnology. They are used for the purification of nucleic acids, proteins, enzymes and plant viruses, supporting genetic engineering, molecular breeding and crop improvement programs. These applications contribute to the development of high-yielding, disease-resistant and climate-resilient crop varieties. Centrifugation has become an indispensable technique in modern agricultural science due to its wide range of applications in research laboratories, biotechnology industries, food processing units, environmental studies and seed technology. In soil science, centrifuges are extensively used for soil texture analysis, separation of clay and colloidal

## Conclusion

Centrifugation is an essential technique in modern agriculture, biotechnology and food industries due to its rapid and efficient separation of particles based on density. Different types of centrifuges are widely used in soil analysis, seed technology, dairy processing, plant biotechnology, microbial studies and molecular research for applications such as DNA extraction, protein purification, cream separation and wastewater treatment. The technique improves accuracy, reduces processing time, enhances product quality and supports sustainable agricultural development. Therefore, centrifugation plays a crucial role in advancing agricultural research, industrial processing and modern scientific innovations.

## References

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