DESIGN AND DEVELOPMENT OF A PORTABLE SPICE ROASTER CUM GRINDER

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Abstract — Spices play a vital role in food products by enhancing the flavor, aroma, and nutritional value. The overall quality of the spices relies on a proper roasting and grinding process. By using methods, we can't achieve the best quality of spice powders because these processes may lead to the damage of volatile compounds, excessive moisture removal, and uneven roasting of spices. To avoid such problems, we have designed a portable spice roaster cum grinder in a compact size for the usage of households and small-scale industries .Our system integrates roasting and grinding using Arduino-based control mechanism to ensure controlled time and temperature during the processing time. Experimental trails were done for the coriander and cumin seeds.

For coriander (initial weight: 25 g), the efficiency increased gradually from 1.6% to 6.4% with increasing roasting time. The optimum condition was selected at Trial 7, where the final weight was 23.5 g with an efficiency of 6%. At this stage, uniform light brown color, strong aroma, and absence of burning were observed, indicating effective roasting.For cumin (initial weight: 25 g), the efficiency ranged from 2.0% to 6.8%. The optimum condition was achieved at Trial 6, with a final weight of 23.4 g and an efficiency of 6.4%. Cumin showed slightly higher efficiency due to its smaller size and higher surface area, allowing faster heat transfer and moisture removal.Grinding efficiency reached 100% at 25 seconds for coriander and 20 seconds for cumin, producing fine powder of uniform particle size. The developed system demonstrated improved efficiency, consistency, reduced processing time, and better retention of flavor and aroma.

Keywords- Portable Spice Roaster cum Grinder, Spice Processing, Roasting Efficiency, Grinding Efficiency, Temperature, Aroma Retention, Coriander, Cumin

I. INTRODUCTION

Spices have played a very important role in human food culture for centuries. Spice not only gives taste and Aroma but also provides nutritional and medicinal values. Spices are obtained from various parts of the plants, such as seeds,roots, bark and fruits and are widely used in both domestic cooking and commercial food production.

India is highly known for its spice production at the global level, and being one of the largest consumers and exporters of a wide range of spices. To maintain the quality of spices throughout the exporting timeline, the spices are well processed and packed to maintain the good quality of spices. The processes used for spices to improve shelf life and usability are roasting and grinding. Roasting and grinding are the two main stages in the spice processing unit, as they directly influence the final quality of the product. Roasting improves flavour, Aroma, activates essential oils, reduces moisture content and improves the colour of the spices.

Grinding helps in reducing the particle size, allowing for better flavour release and uniform mixing of food products. The steps can be done both in traditional and modern ways, when it comes to the traditional way it has many limitations and may lead to a large amount of wastage if it is not properly processed ,like manual pan roasting method depends on heavily on operator skilled person to handle it because it may lack proper temperature control leading to uneven roasting and burning similar to this conventional grinding methods generate excessive heat due to friction which also leads to loss of Aroma and degradation of heat sensitive compounds present in spices.

Recent research tells that during normal grinding, there may be a heat generation which goes up to 90 degrees Celsius. This will degrade the quality of spices. Recent technologies may rectify this problem using cryogenic grinding methods, but it is more expensive and not practical for household and small-scale industries. As a result, there is a growing demand for simple, affordable and efficient systems.

Combining the roasting cum grinder into a single compact integrated system gives us.This device offers several advantages, such as reducing process time, minimizing manual handling, lowering contamination risk, and ensuring overall consistency. With automation—using a micro-controller to control roasting and grinding times—the process becomes more precise, helping retain better flavour and aroma. Its portability makes the device especially beneficial for households, small-scale industries, and cottage industries.

Based on the requirements, the project aims to design and develop a portable spice roster cum grinder into a single compact unit. The system uses an Arduino-based control mechanism to ensure uniform roasting and timed grinding. This approach improves spice quality, taste , flavour, Aroma retention and even improves the shelf life of spices. This gives a practical solution for small-scale spice processing industries.

II. LITERATURE SURVEY

Spice processing,plays a crucial role in determining the final quality of the product, including flavour, aroma, colour, and nutritive value. Controlled heat applied during roasting induces physio-chemical reactions that release aromatic compounds responsible for the sensory profile of spices (Martins et al., 2019). Uniform heat distribution during roasting ensures the preservation of bio-active compounds (Fikry et al., 2019). However, conventional roasting methods rely on manual operation, resulting in inconsistent quality among batches (Srinivasan, 2019).

The presence of high moisture content and the complex composition of spices further complicate the roasting process. Retention of volatile oils, which are essential for aroma and flavour, is highly affected by variations in temperature and time.(Srinivasan, 2019). Manual roasting often fails to maintain the required roasting parameters, thereby creating a need for technological intervention and monitoring systems. Embedded systems in the food industry enable real-time monitoring and control of processing conditions (Ahmed and Khan, 2020). Traditional roasting methods depend on manual stirring and visual inspection, which lead to non-uniform and inconsistent heating (Patel and Joshi, 2018).

Grinding is another critical stage in spice processing that determines the quality of the powder and particle size distribution. Traditional grinding methods, such as stone grinding or mechanical grinding, generate excessive heat due to friction. This heat leads to the loss of volatile oils and essential compounds, thereby degrading the nutritive value and flavour of spices. Conventional grinding can increase product temperature up to 90°C, causing significant quality deterioration (Kumar et al., 2019). Zhou et al. (2020) reported that frictional heat generated during high-speed grinding adversely affects the physio-chemical properties of spices.

Advanced techniques such as cryogenic grinding utilize low-temperature liquid nitrogen to minimize heat generation during grinding. This method effectively preserves the physio-chemical properties of spice powders, reduces particle agglomeration, and improves flow properties. However, the major disadvantage of cryogenic grinding is its high operational cost (Mujumdar, 2019).

Non-uniform particle size negatively affects packaging properties and powder flow ability. The blade design and rotational speed significantly influence grinding performance; therefore, careful operational design is required to achieve optimum results (Aguilera and Stanley, 2019). The integration of sensors and display systems enhances monitoring by incorporating LCD displays and alert systems to indicate the completion of each process (Ramesh and Patel, 2020).

Kumar and Das (2020) emphasized the need for controlled roasting and grinding operations to ensure product affordability and quality. Automation in food processing reduces labour requirements, enhances hygiene, improves consistency, and makes the system suitable for small-scale industries (Lee et al., 2021). Research by Kulkarne et al. (2020) demonstrated that improper sieving leads to segregation of fine and coarse particles, resulting in inconsistent product appearance. In small-scale industries, reprocessing can be minimized by integrating automatic sieving systems (Deshpande, 2021). Proper processing techniques also reduce particle agglomeration and microbial growth during storage and distribution.

Extended exposure of spice powders to light and air leads to lipid oxidation and moisture absorption, which alter composition, texture, and functional properties, thereby reducing shelf life (Farah and Donangelo, 2018).

III. MATERIALS AND METHODS

The development of the portable spice roaster cum grinder needs the required mechanical,electrical and electronic components to ensure structural stability,hygienic processing, automation and safe power operation. According to functional requirements durability, cost effectiveness and compatibility each materials and components were selected.

3.1 ROASTING CHAMBER

The roasting chamber is the most important component of the system. The material used ensures corrosion and high temperature tolerance by providing efficiency. During roasting, the sample are exposed to optimum temperature, the material prevents chemical reaction between the chamber surface and the sample,thereby preserving flavour integrity.

The chamber is designed to allow uniform heat transfer from the surrounding heating coil with the help of the agitator. The smooth internal surface of the chamber reduces clumping of the sample.

The agitator is used for uniform roasting with continuous mixing of the spices to avoid overheating. A DC gear motor with an attached shaft was used as the agitator mechanism. The gear motor provides controlled rotational speed and sufficient torque to rotate the shaft inside the roasting chamber . It will improve the roasting consistency and aroma development by slow and steady agitation of spices.

3.2 HEATING COIL

A reliable and consistent heat source is required for the roasting process. A 230V AC heater coil is used as a heating element. The heating coil surrounds the chamber to ensure uniform heating. The electrical energy is converted into thermal energy by a coil through resistive heating.

The temperature inside the chamber increases gradually, thereby controlling the moisture. The relay module is connected to the heating coil, which allows the micro-controller to switch it on and off,preventing overheating of spices.

3.3 AGITATOR

The gear motor provides the controlled rotational speed and sufficient torque to the mixing shaft inside the roaster chamber, which will avoid overheating.

The DC gear motor with an attached shaft was used as the agitator mechanism. The agitator will provide uniform roasting and continuous mixing of the sample. Improving roasting consistency and aroma development by the slow and steady agitation.

3.4 GRINDING CHAMBER

Mechanical impact and shear forces are involved in grinding, and the material must resist mechanical stress. The material used resists abrasion caused by the grinding of hard spices. It also prevents rusting and ensures uniform grinding.

The AC grinding motor operates at 1000 RPM, providing sufficient rotation speed and force to pulverise spice into powder. Frictional heat generation is reduced by controlling speed, ensuring effective size reduction. The relay and controller activate the motor for a preset time to produce a consistent product.

3.5 MICROCONTROLLER

Arduino UNO acts as the central control unit of the system. It activates the motor, displays the update, allows input, monitor temperature. The time set for roasting and grinding are controlled.The temperature is controlled by using an LM35 temperature sensor. It allows future modifications and system updates.

3.6 TEMPERATURE SENSOR (LM35)

The sensor monitors the roasting chamber temperature providing analog voltage output that is equivalent to temperature in degree Celsius.It allows dynamic control on the heating process and prevents over heating or under heating of spices and improves aroma retention. The LM35 sensor is accurate and simple to handle.

3.7 DISPLAY UNIT

A 16x2 liquid crystal display (LCD) is used to monitor the system, providing information. It shows temperature reading, time, operation (roasting or grinding) and completion. It reduces error and brings operational clarity.

3.8 POWER SUPPLY UNIT

The AC and DC power were required in this system for different components. The power supply unit consists of a step-down transformer, which reduces the 230V AC input to a lower AC voltage according to the electronic circuits.

A rectifier, which converts AC voltage into pulsating DC, whereas the Filter circuit will smooth the DC output. The voltage regulator will provide a stable 5V DC supply for Arduino and other low-voltage components. This regulated power system provides the safe and stable operations of electronic components.

3.9 CONTROL DEVICES

High-power devices, such as the heating coil and AC grinding motor, are controlled by relay modules. They play as electrically operated switches, enabling safe control of high voltage loads using signals from the Arduino.For selecting operation modes and setting time parameter controlled by push buttons.These input device allow simple and user friendly interaction with the system.

3.10 BUZZER

It helps to know the roasting and grinding cycles are completed by providing audible alerts.This feature will reduce the continuous monitoring of the operation and will enhance the user convenience.It also servers the safety alert mechanism in case of abnormal operations

IV. METHODOLOGY

The raw material used are Cumin seeds and coriander seeds are selected. Foreign particles such as dust and stones are removed manually,

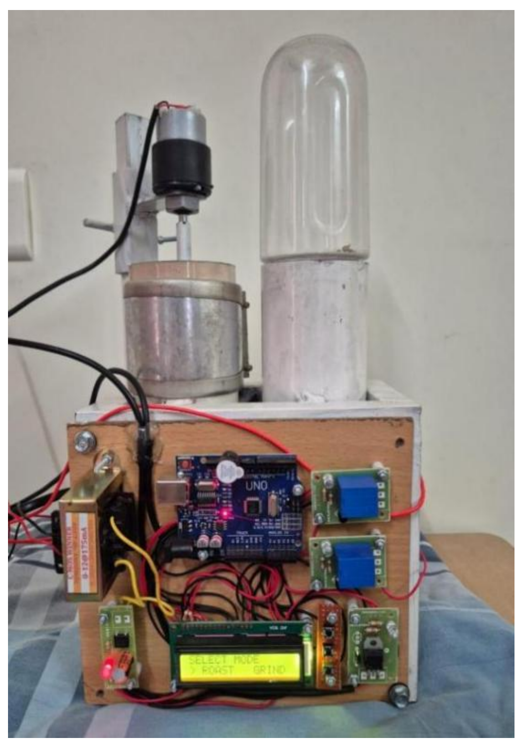

Figure 4.1 Portable spice roaster cum grinde

thereby reducing external contaminants affecting the process. About 50g of sample is taken for this process. The roasting chamber is surrounded by an AC heating coil to ensure uniform heat distribution throughout the process.

A DC motor is used to rotate the agitator to Ensure continuous mixing of the sample. The sample is fed into the roasting chamber and the LCD displays the mode of action and the time period set for each process. Push buttons are used to set the mode and the time for roasting in seconds once it is Set it, and the agitator starts to rotate and mix.

The sample and the AC heating coil produce heat required for roasting. The LM35 temperature sensor monitors the temperature, and it is displayed on the LCD. Buzzer alerts once the roasting is done top re-set time, indicating the end of roasting process. The sample is left to cool.

4.1 GRINDING:

Once the samples are cooled naturally, it prevents further heat exposure and avoids condensation during grinding. A high speed.The AC motor (1500 RPM) grinds the sample.within seconds. The mode of action is set to Grinding and time for grinding are set in seconds.

The samples are fed into grinding chamber and closed properly, and the set time is entered. The buzzer alerts the end of grinding process. The ground samples are collected from the chamber. Final end product of very fine particle size is received.

Figure 4.2 Grinding chamber with blade

4.2 WORKFLOW:

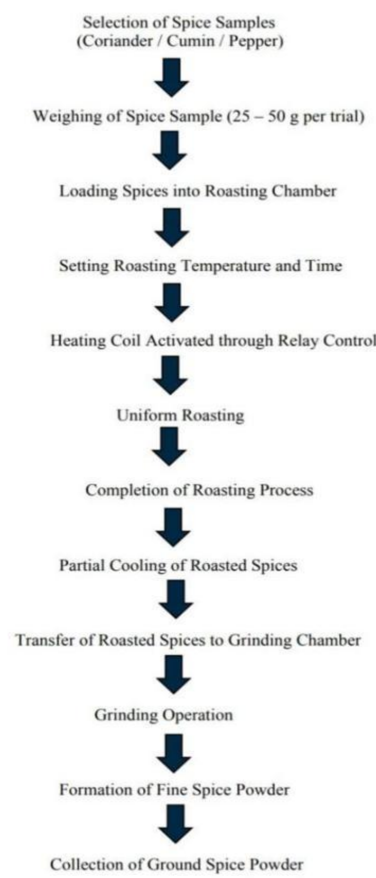

Figure 4.3 Flow Diagram

V. RESULT AND DISCUSSION

5.1 ROASTING EFFICIENCY ANALYSIS:

The performance of the spice roaster cum grinder was analyzed through experimental trails using coriander and cumin as samples. The results were analyzed based on roasting efficiency, grinding efficiency, colour intensity (RSM) and overall product quality.Roasting efficiency was determined based on weight reduction of the sample after roasting,which indicates moisture loss and release of volatile compounds.

5.1.1 FORMULA USED:

Roasting Efficiency (%) = $W_i - W_f/W_i$ x100

Where

- W_i = Initial weight of sample
- W_f = Final weight after roasting

5.2 TRIAL AND ERROR :

1) Coriander (Initial Weight = 25 g)

TRIAL	FINAL WEIGHT	EFFICIENCY (%)
1	24.6	1.6
2	24.3	2.8
3	24.0	4.0
4	23.8	4.8
5	23.7	5.2
6	23.6	5.6
7	**23.5**	**6.0**
8	23.4	6.4
9	23.4	6.4
10	23.5	6.0

Optimized Value Selected: 23.5 g

Efficiency=25−23.5/25×100=6%

2) Cumin (Initial Weight = 25 g)

TRIAL	FINAL WEIGHT	EFFICIENCY
1	24.5	2.0
2	24.2	3.2
3	23.9	4.4
4	23.7	5.2
5	23.6	5.6
6	**23.4**	**6.4**
7	23.5	6.0
8	23.3	6.8
9	23.3	6.8
10	23.4	6.4

Optimized Value Selected: 23.4 g (Trial 6)

Efficiency=25−23.4\25×100=6.4%

Based on both efficiency and quality parameter was selected as the optimum roasting condition.The maximum efficiency was observed at Trial 8 and 9, the improvement beyond Trial 7 and 6 was minimal, indicating a saturation point. The uniform color development, strong aroma, and no signs of over-roasting were observed. In Trial 7 (23.5 g, 6%),Trial 6 (23.4 g, 6.4%) so the efficiency at this stage was found to be stable and repeatable. Hence, Trial 7 and Trial 6 provided the balance between effective moisture removal and quality retention.

5.3 ANALYSIS AND DISCUSSION:

These sample coriander and cumin represent a gradual increase in roasting time, which obtains the roasting efficiency value. This shows that as the roasting duration increases, the moisture content and volatile components are progressively reduced, resulting in weight loss.The efficiency values were lower, around 1.6% - 3% in the initial trials ,which indicates the insufficient roasting and incomplete moisture removal. As the roasting time increased the efficiency will also improve gradually, reaching an optimum range of % for coriander and 6.4 % for cumin.

Only a marginal increase in efficiency was observed, which suggests that roasting does not significantly improve moisture removal but may lead to over-roasting or degradation of quality.The higher efficiency observed in cumin compared to coriander can be attributed to its smaller seed size and higher surface area, which allows rapid heat penetration and moisture removal.

The efficiency was further supported by physical observations by uniform light brown color was obtained.Strong aroma was developed and no carbonization was observed. The results demonstrate proper moisture removal, uniform heat distribution, and improved product quality without compromising aroma or causing thermal degradation.

The graph illustrates the variation of roasting efficiency with respect to trial number for coriander and cumin samples. It is observed that the efficiency increases steadily with increasing roasting time due to progressive moisture removal. After reaching the optimum condition (around Trial 7–8), the efficiency shows a plateau, indicating that further roasting does not significantly improve performance. This confirms that the selected roasting conditions are optimal for achieving uniform roasting without over-processing.

From the graph, we can clearly see that efficiency increases initially and then stabilizes, which indicates that optimum a roasting condition has been achieved.

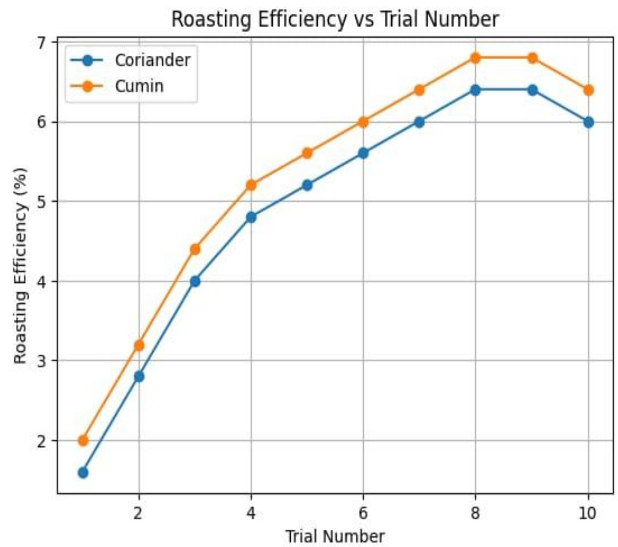

Figure 5.1 Roasting efficiency vs Trial

5.4 OPTIMIZATION OF ROASTING TIME BASED ON COLOR INTENSITY ANALYSIS :

To determine the optimum roasting time of coriander and cumin seeds, the portable spice roaster cum grinder was used for the experiment.A total of ten trials were conducted for each spice - starting with 1 minute and gradually increasing 30 seconds until 7 minutes. There were changes in aroma and color after roasting.

In our project we have used ImageJ software to analyse the color intensity as it wasn't distinguishable to the naked eye. Images of initial, intermediate, and final samples were analyzed using ImageJ.There was a visible change in mean value of color intensity indicating the roasting.

5.5 IMAGE J-BASED COLOUR INTENSITY VALUES AT DIFFERENT ROASTING TIME :

SAMPLE	STAGE	TIME	MEAN
Cumin	Initial	1 min	89.9
Cumin	Intermediate	3 min	98
Cumin	Final	6 min	111.4

Table 5.1: Cumin colour intensity

SAMPLE	STAGE	TIME	MEAN
Coriander	Initial	1 min	86.3
Coriander	Intermediate	3 min	101.4
Coriander	Final	5 min	113.7

Table 5.2: Coriander colour intensity

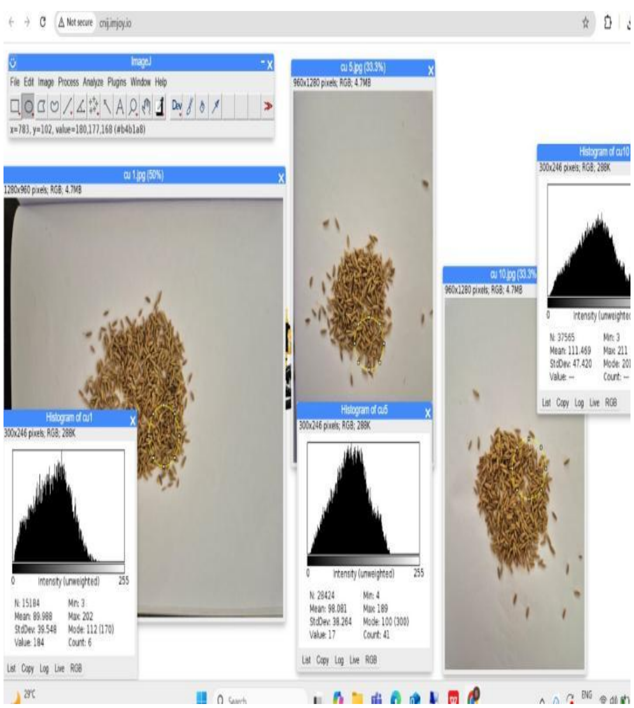

Figure 5.2: Cumin color intensity analysis

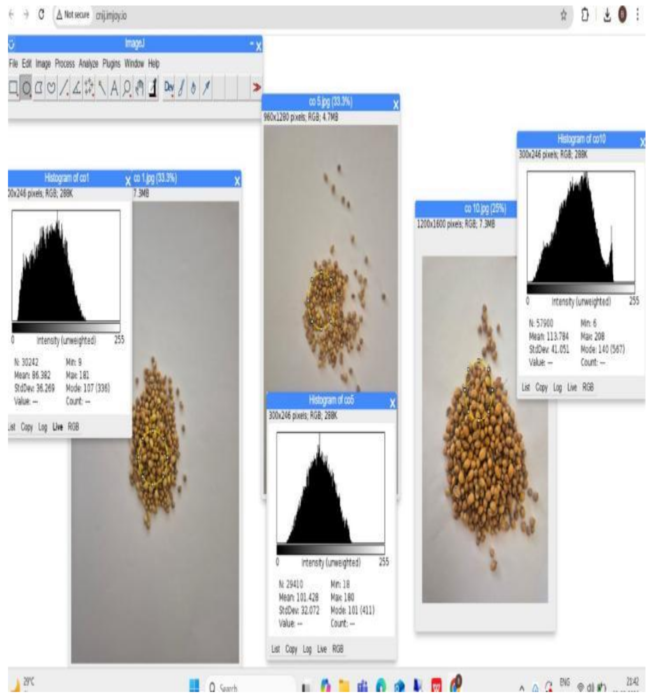

Figure 5.3: Coriander color intensity analysis

This graph shows an increase in mean color intensity with an increase in roasting time. Increase in color intensity is the result of thermal reaction during heating. To attain the optimum roasting temperature it takes 5 minutes for coriander and 6 minutes for cumin to differentiate aroma and color.

5.6 GRINDING EFFICIENCY ANALYSIS:

The grinding efficiency of the portable spice roaster cum grinder was evaluated by taking 20 g of both cumin and coriander at intervals of 5 seconds each. The ground spice is sieved through a 500 µm sieve to separate coarse and fine powders.

The efficiency of the grinding is calculated.Using the formula for the weight of fine powder to the total sample taken and multiplied with 100% to get the value in percentage for cumin overall time period to get the standard value of spice powder, it took 20 seconds, and the coriander took 25 seconds due to its large size.

5.6.1 FORMULA USED:

Grinding Efficiency = Weight of the fine powder/Weight of the total sample taken x 100

1) Particle Size: 500µm
Sample 1: Coriander

Time	Sample Weight	Coarse particle	Fine particle	Efficiency
5	20	11.2	8.8	44%
10	20	7.2	12.8	64%
15	20	4.1	15.9	79.5%
20	20	2.8	17.1	86%
25	20	0	20	100%

Table 5.3 Grinding efficiency of coriander

2) Particle Size: 500µm
Sample 2: Cumin

Time	Sample Weight	Coarse particle	Fine particle	Efficiency
5	20	10.4	9.8	49%
10	20	5.7	13.5	67.5%
15	20	3.7	16	80%
20	20	0	20	100%

Table 5.4 Grinding efficiency of cumin

V. CONCLUSION

The study designed and developed a portable spice roaster cum grinder as an efficient solution for spice processing. It combines roasting and grinding operations into a single compact unit,reducing manual labor, processing time, and risk of contamination.The Arduino-based controller system ensures precise roasting and grinding time preventing overheating or under heating of spices thereby, producing uniformly roasted sample. Samples taken for the experiment: coriander and cumin developed aroma and color during roasting with optimal moisture removal, efficiency of about 6% for coriander and 6.4% for cumin.

The trial and error method provides optimum roasting condition with an increase in time. ImageJ software was used to indicate change in color intensity that wasn't visible with naked eye. The change in mean value of color intensity from 89.9 to 111.4 for cumin and from 86.3 to 113.7 for coriander indicates the rate of roasting of samples. Grinding efficiency was high with very little duration producing uniform and fine particles without generating excess heat and maintaining high quality of spice. For cumin it took about 20 seconds and for coriander it took 25 seconds. Efficiency for both roasting and grinding was found using the formula method.

Overall, the developed system is reliable in terms of efficiency, uniformity, quality, and aroma. Compared to conventional methods our system offers a cost-effective and energy efficient solution applicable for household and small-scale spice processing industries. It improves scalability of spice processing with enhanced quality of spice powder.

VI. FUTURE WORK

In a compact system, the developed portable spice roaster cum grinder demonstrates effective integration of roasting and grinding to enhance the performance, efficiency, usability of the system, and several improvements can be considered in the future work. In the current prototype, basic temperature monitoring, and control are used. Advanced temperature control techniques such as PID control are the one possible improvement.The consistency of roasting which help preserve the natural aroma,f lavour, and nutritional properties of spices,by incorporating more precise control algorithms that the system can maintain more stable roasting temperatures.The integration of Internet of Things (IOT) technology was another potential development of the system in addition of adding wireless communication modules such as Wi-Fi or Bluetooth, which allow the system to be control remotely monitoring and mobile application.This application will help the user to track roasting temperature, processing time, and machine status in real time, which improving the convenience and operational flexibility.

The automated spice transfer mechanism between the roasting and grinding chambers which was the future version of the system is included. In the present working model partial manual handling may still be required by introducing an automatic transfer system would reduce the manual work and improve the overall efficiency of the system.The effective roasting performance was maintained by consumption of less power and can help the use of energy-efficient heating elements and motors, along with improved insulation in the roasting chamber.Further research can focus on optimizing the grinding mechanism by exploring different types of blade designs and grinding speeds for various types of spices, which allow the system to produce even particle size and improves the quality of the final spice powder.

The advanced mechanism design of the system can also be enhanced to improve the durability, hygiene, and ease of cleaning.The modular structure design would make the equipment more suitable for long-term use in the small-scale food processing industries and household uses. Finally, future work could involve the extensive experiment testing with different spice varieties such as coriander, cumin, pepper, and turmeric to evaluate the roasting and grinding efficiency, with overall quality parameters.Related studies would also help to improve the operational conditions and overall reliability and applicability of the system.

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