ISSN 2250-3153

Model Development of Evaporative Water Cooling (EWC) grinding system for improving grinding quality of spices

D.M.S.P Bandara[*], K.S.P Amaratunga[**], T.M.R Dissanayake[*], C.R Gunawardana[*]

[*]Institute of Post Harvest Technology, Anuradhapura, Sri Lanka

**University of Peradeniya, Sri Lanka

Abstract- Study on the Evaporative Water Cooling (EWC) grinding was performed by the use of a new model development as the novelty of spice grinding industry in order to control the temperature increase during grinding due to size reduction inside the grinder. The developed Evaporative Water Cooling grinding process consisted of three main units, namely water atomizing unit, dehumidified air supplying unit and grinding unit with vibratory hopper. The water atomizing unit is a cooling device designed of other sub parts, namely water pressure pump and knapsack nozzle, produced atomized water vapor in to the grinding system. The function of the water atomizing unit of Evaporative Water Cooling grinding system is to absorb the heat, which is generated due to the size reduction process during grinding. In this experiment, comparative study in between the conventional grinding and Evaporative Water Cooling grinding with different water rates was done for obtaining analytical results in terms of retention capsaicin content, final moisture content, temperature increase/decrease during grinding, water activity of final product, final product color and specific energy consumption. The tests based on the MI-2 chili variety revealed that it could be successfully ground at a feed rate of 30 kg/hr, reducing the temperature by 12±1.53 degrees under the water spray rate of 2.1kg/hr. The maximum Capsaicin recovery was yield by 15% higher than the conventional grinding. The water activity in all the Evaporative Water Cooling grinding samples are within the allowable range and specific energy consumption is non-significant among both trials; the Evaporative Water Cooling grinding and the conventional grinding. The study indicated that the Evaporative Water Cooling Grinding is considerably influenced by the grinding properties among the parameters studied.

Index Terms- Spice grinding, Evaporative water cooling, Quality of spices

I. INTRODUCTION

Use of spices has a valuable greater history compared to any other matters used by the human. Viuda-Martos et al, 2011 reveal that the history, the date back to 5000 BC documentarily evidence has been found on the use of thyme which is one of spices by the Sumerians. In 2000 BC a precursor of curry was used in India, while Egyptian papyruses from 1555 BC mention the use of coriander, funnel, juniper, cumin, garlic and thyme and dried mint dating from 1000 BC has been found in pyramids from the same country (Block, 1986).

Spices are very important part of preparation of meals among all over the culture of the world. Spices and aromatic herbs have been used since antiquity as preservatives, colorants, and flavor enhancers. Spices have long have been the basis of traditional medicine in many countries, have also been the subject of study, particularly by the chemical, pharmaceutical, and food industries, because of their potential use for improving health. Both in virtro and in vivo studies have demonstrated how these substances act as antioxidants, and hypolipidemics and show antibacterial, anti-inflammatory, antiviral, and anticancerigenic activities. These beneficial physiological effects may also have possible preventative applications in a variety of pathologies. The aim of this review is to present an overview of the potential of spices and aromatic herbs as functional foods (Viuda-Martos et al, 2011).

Spice milling is an ancient industry, akin to the cereal milling industry, with the difference that in spice grinding there are additional problems of the volatility of essential oils naturally present therein (Pruthi, 1980). As a result in 1998, a cryogenic grinding system has been designed and developed to cool the spices before feeding to the grinder and also maintain the cryogenic temperature in the grinding zone by Singh and Goswami. Study on ambient and cryogenic grinding was performed to test the novelty of cryogenic grinding and pin point the drawbacks of ambient grinding. Comparative study had shown that ambient grinding need more power (8.92%) and specific energy (14.5%) than cryogenic grinding. Particle size analysis had shown that cryogenic grinding produced coarser particles. Comparative study of energy law constant shows that ambient is more power consumptive. The higher amount of volatile oil (2.15 ml/100 g) content was found in cryogenic grinding and also powder of freshness and lower whiteness (40%) and higher yellowness (14%) indices found for cryogenic grinding (Meghwal and Goswami, 2010).

In this design study, the alleviation of heat stress in grinding chamber have been tried of lowering by the latent heat of vaporization of water whereas dehumidified air was being a facilitator to drag out of moist air from the system. Evaporative cooling is based on a physical phenomenon in which evaporation of a liquid usually water into surrounding air cools an object or a liquid in contact with it. As the liquid turns to a gas, the phase change absorbs heat. Technically, this is called the “latent heat of evaporation”. Water is an excellent coolant because it is plentiful, non toxic and evaporates easily in most climates.

Besides, chilli (*Capsicum Annum L.)* was used to test the system because it is an important spice providing pungent, color and appetizing effect to the cousins and various factors affect the stability of capsaicin which isidentified as the primary pungent principle in Capsicum fruitswith $C_{18}H_{27}NO_3$ molecular formulae. And less research carried out on it is also the basis for selecting chilli as the raw material in this study. It was important to find out the chemical characteristic of Capsaicin selecting for chemical analysis procedure. According to the PubChem data base of U.S National Library of Medicine, United states, it is stated that the color of Capsaicin is pure dark red and solid base. It is highly volatile and the melting and the boiling points are 210-220°C and 65°C respectively. Moreover Capsaicin is insoluble in water by 28.93 mg/Laround 25^0C (Lewis, 2012 and O'Neil, 2013).C

II. DESIGN AND DEVELOPMENT

The evaporative water cooling unit consisted of three main units, namely water atomizing unit, dehumidifier air supplying unit and grinding unit with vibratory hopper. The schematic diagram is shown in figure 1.

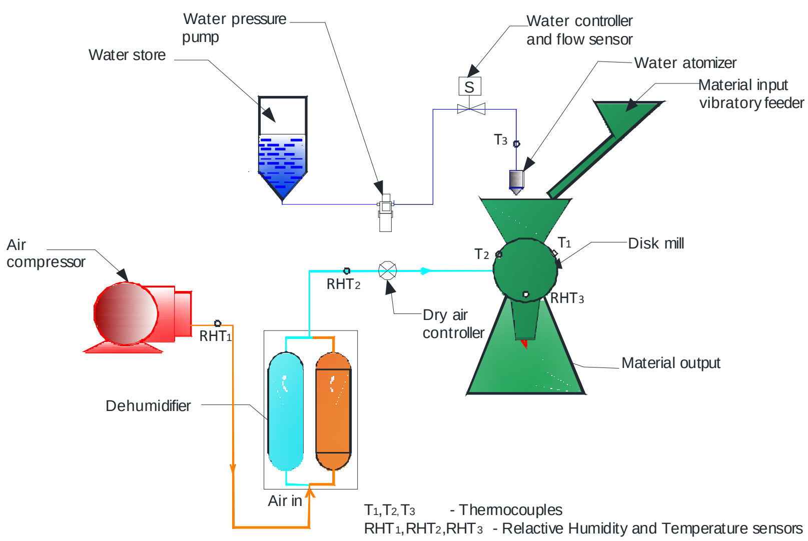


Figure 1.Schematic diagram of evaporative water cooling (EWC) spice grinding system

Water atomizing unit

The water atomizing unit is a cooling device designed of two other sub parts, namely water pressure pump (model:CH-1260) and knapsack nozzle (model:SIBAOLU-001), capable of producing atomized water spray in to the grinding system as shown in Figure 1. The function of the water atomizing unit of EWC grinding system is to absorb the heat, which is generated due to the size reduction process during grinding and giving barrier to absorb heat to the grinding product. Here atomized water vapor absorbs the heat generated during grinding as the latent heat more and less amount of sensible heat. But the evaporated water vapor must be facilitated to be blown out from the system before depositing on the ground product. This function is able to get fulfilled by a dehumidified air flow. The water consumption is calculated according to the energy balance laws of heat transfer and manipulated using electronic and mechanical controllers such as flow sensors, solenoid valves and non-return valve.

Dehumidifying air supplying unit

The purpose of having this type of apparatus to this EWC system as stated above is to remove the moist generated in the grinding chamber due to artificial humidification. For this, a Dehumidifier known as refrigerating air dryer (Model: ELRD20) was used. Air supply to the air dryer is obtained from the air compressor (Model: V-O-25 CU). Air flow from the dehumidifier is connected through a high pressure flexible fluid duct to the center of grinding chamber and it is manipulated by flow sensors and air pressure control valves.

Grinding unit with vibratory feeder

There are three types of chili grinding machinery commonly available in the Sri Lankan market. Small and medium scale spice processors are widely using plate mill and pin mill which are the most popular and simple grinding mills in Sri Lankan spice processing industry. Hence, of these two types disk mill was selected for testing EWC grinding evaluation of performance. There are four types of pin mills according to the capacity. In this study, the machine UD 23 which consists of rotating disk having diameter of 0.23 m and 4 kW motor was selected for the experiment. Throughout the experiment the internal screen attached to the grinding chamber was maintained with 500 micron perforation. This machinery is fabricated by Udaya Industries, Weligalle and installed at Institute of Post-Harvest Technology, Anuradhapura, Sri Lanka. Component drawing of the disk mill used by the research study is shown in figure 2.

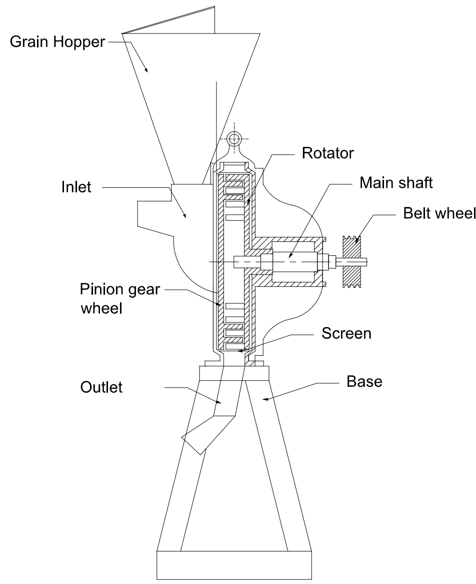


Figure 2. Component drawing of the disk mill UD 23

To feed the materials with different feed rates throughout the experiment, a vibratory feeder is developed for attaching a variable frequency drive (VFD).The frequency is calibrated according to the rated capacity of the grinder.

Calculation of water consumption and dry air flow

The heat to be discharged at EWC grinding is composed of heat which is generated at the size reduction of feed material and the heat introduced by the drive capacity of the mill provided that the cooling effect required for the operation of the grinding chamber is met by spraying atomized water vapor into the system that must be blown out of the system by the use of dehumidified air. When consider the grinding system there are different kinds of energy in put to the system as follows.

-Size reduction of the chili
-Heat absorbed by the chili powder
-Heat absorbed by the dry air
-Evaporation of the water (latent heat)
-Heat absorbed by the water (sensible heat)

Motor power for grinding action

Power in = $\sqrt{3}VI_L \csc \emptyset$

V =Voltage of the motor

I_L =current in load condition

$\csc \emptyset$ =power factor

Measuring the current of the motor without loading the motor (without input chili, water, dry air) is no load current. Similarly measure the current when the material and air input allowed for the loaded condition current is load current.

Assume that the current do not very for different water flow rates and the fixed chili and dry air flow.
For single phase motor: power = $VI_L \cos \emptyset$
For three phase motor: power = $\sqrt{3}VI_L \cos \emptyset$

$$\sqrt{3}V(I_L - I_O)\mu \csc\emptyset = (\dot{M}_{c.in} - \dot{M}_{c.in} \times a\%).C_{chili}(T_s - T_{amb}) + \dot{m}_{a.in}.C_{air}(T_s - T_{a.in}) + \dot{m}_{w.in}.L_W + \dot{M}_{c.in} \times a\%. \quad (13)$$

Rilationship between in put water rate and the system temperature: T_s, $\dot{m}_{w.in}$

$$k_2 = k_m C_{chili} T_s - k_m C_{chili} T_{amb} + \dot{m}_{a.in}.C_{air} T_s - \dot{m}_{a.in}.C_{air} T_{a.in} + \dot{m}_{w.in}.L_W + \dot{M}_{c.in} \times a\% L_W$$

$$\dot{M}_{c.in} - \dot{M}_{c.in} \times a\% = k_m$$

$$T_s(k_m C_{chili} + \dot{m}_{c.in}.C_{air}) = \left(k_2 - k_m k_1 + k_m C_{chili} T_{amb} - \dot{m}_{a.in}.C_{air} T_{a.in} + \dot{M}_{c.in} \times a\% L_W\right) + \dot{m}_{w.in}.L_W$$

$$a(constant) = \left(k_2 - k_m k_1 + k_m C_{chili} T_{amb} - \dot{m}_{a.in}.C_{air} T_{a.in} + \dot{M}_{c.in} \times a\% L_W\right)$$

$$b(constant) = (k_m C_{chili} + \dot{m}_{c.in}.C_{air})$$

$$T_s = \frac{\dot{m}_{w.in}.L_W + a}{b}$$

$$T_s = \left(\frac{L_W}{b}\right)\dot{m}_{w.in} + \frac{a}{b} \quad (14)$$

But, externally inserted water must be blown out from the system otherwise water vapour can be deposited in the ground product.

Dehumidified air flow was produced to the system through out the process $\dot{m}_w$ could be carried away by the dehumidified air flow. The ratio of moisture addition to the air equal to the flow rate of water
Injected is determine by the water vapour mass balance.

$$\dot{m}_w = \dot{m}_a \ (W_2 - W_1)$$

Where W_1 = Initial humidity ratio of humidified air injected to the system from the dehumidifier at $T_{a.in}$

W_2 = Final humidity ratio of air leaving from the system at T_s

Assuming that heat generated inside the grinder during grinding that is totally converted from mechanical force produced by the the single phase 5 hp motor is used to evaporate water injected and moisture content of feed material.

Current drawn by the motor under the condition of No load and Load condition is tested using clip on ampere meter (DT226 CLAMP METER HOLD and actual mechanical force inserted to the grinder calculated. Rated capacity of UD 23 is taken as 30kg/hr for the testing.

$$I_O = 4.9\,A \qquad I_L = 11.9\,A \qquad V_O = 230v \qquad \dot{M}_{c.in} = 30kg/hr$$

Therefore, maximum water required for absorbing heat dissipated is calculated.

$$(230v \times 11.9\,A \times \cos\emptyset \times 3600s)/1000 = \dot{m}_{w.in} \times \frac{2256kJ}{kg} + 30 \times 7.95\% \times \frac{2256kJ}{kg}$$

$$\dot{m}_{w.in} = 1.98kg/hr$$

At the maximum water sprayed to the system, the dry air needed for carrying evaporated water is calculated as below. The maintaining set temperature (T_s) inside the system is assumed as 35^0C and dry air inserted to the system from the Dehumidifier (ELRD-020) is maintained at 20^0C and 20% humidity. From Phsychometric chart, W_2 and W_1 were taken.

$$\dot{m}_w = 0.021\dot{m}_a$$

$$\dot{m}_a = 94.40kg/hr$$

III. MATERIALS AND METHOD

Materials

For the study, dry chilli pods were obtained from Rajangana area, Sri Lanka during December- January, 2016. The variety was identified as MI- 2 and moisture content was found to be 13.9% d.b. at the time of purchasing. The moisture content was measured using Dean and Stark method. Selected homogenious chili pods are cuts into one centimeter length pieces using a sharp scissor and made 500 g samples. Before testing, sample materials were undergone on two hours sun drying and moisture content was reached to 7.95±0.26% d.b.

(a)

(b)

Figure 5. (a) Chili pod and (b) Chilli Pieces

Data Acquisition procedure

To get the experimental parameter such as temperature, relative humidity, water flow rates, dry air flow rate, the different transducers at the relevant places were used as shown in figure 1. Both side of inside the grinding chamber, two thermocouples (Model: MAX6675) were placed and another transducer for sensing relative humidity and temperature two in one (model:AM2305) was attached to the bottom of the chamber closer to the outlet. In order to measure the dehumidified air flow rate, air temperature and relative humidity entered to the grinding chamber, air flow hole transducer (model:YF-S201) and temperature, relative humidity sensor (Model:DHT22) was attached to the air out let of the dehumidifier. Same flow transducer used to measure air flow rate was lined up to water flow directed into the grinding chamber. All the transducers were programmed with Arduino using two Atm ega 328 Micro controller and a network card. The Printed Circuit Board (PCB) drawing of these sensors which was designed for this machinery set up is shown in figure 6.

For experimentation, switch mode power supply, power distribution PCB (Printed Circuit Board), Arduino uno platforms, were fixed in to a plastic enclosure and mounted on a lesser vibrating part of the mill.

For data acquisition at the PC side, a monitoring application which was developed using Java programming language is capable of monitoring realtime sensor data, record sensor data and retrieve previously stored sensor data. For recording sensor data, the MySQL (Standard Query Language) database management system was used.

Since there were multiple sensors connected to the Arduino uno platform, more than one interrupt could fire while running the main programme. So if it is also used for handling communication, the data rate could fluctuate or there could be delays in communication. There fore a second Arduino was used to handle the communication between the sensor setup and the PC side data acquisition program. Ethernet interface was selected for communication between the PC and the sensor setup because of the higher reliability.

The first Arduino was programmed to acquire all the sensor data one by one and when finished update the corresponding sensor values in the communication handling second Arduino. It follows this procedure in a cycle.

Second Arduino was programmed to handle PC side requests and give appropriate responses. When the PC programme request for sensor data, the second arduino creates a response packet with the updated sensor data and send to the PC desktop application. It is also capable of processing other command requests such as opening and closing water flow valves.

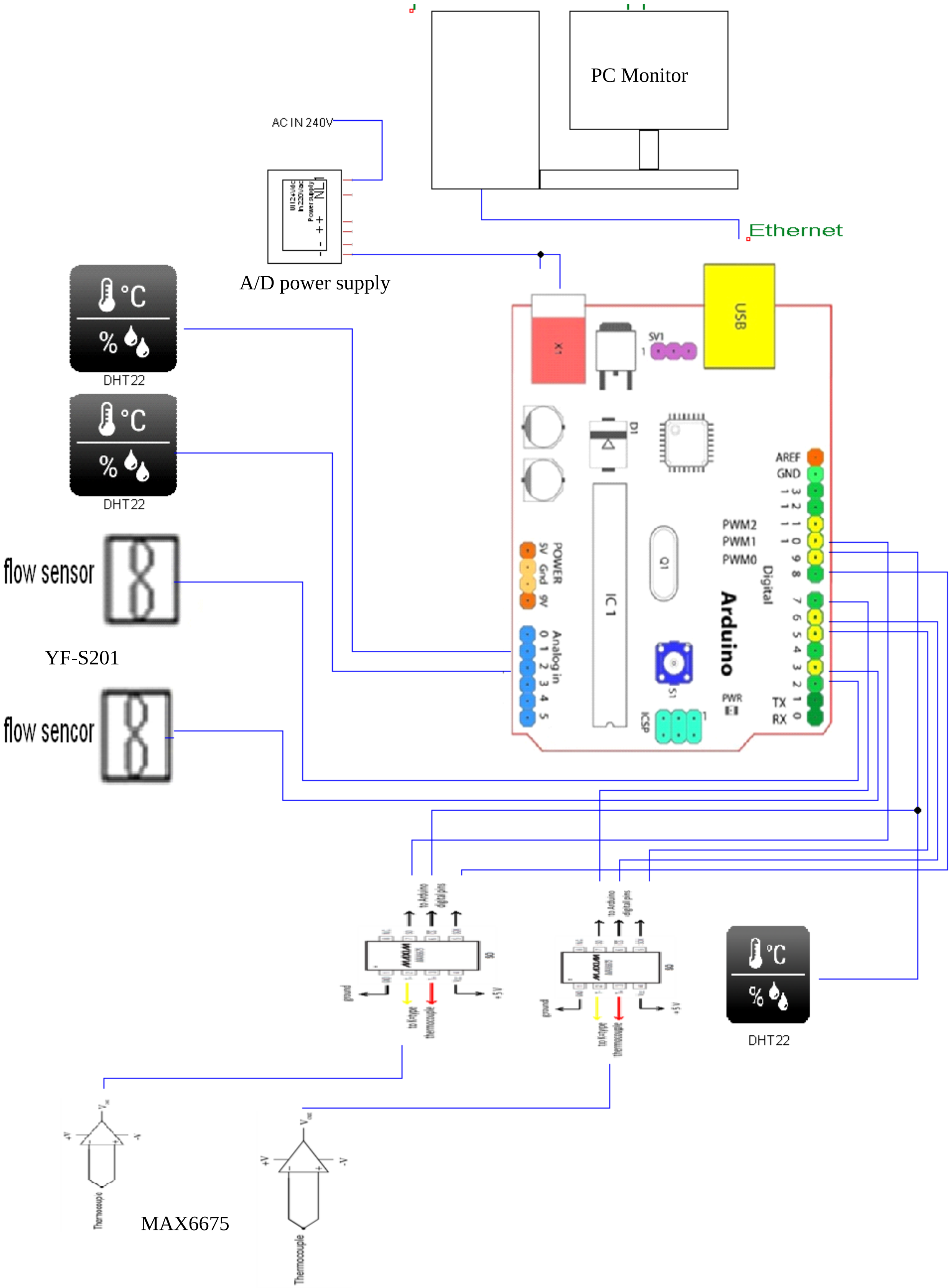


Figure 6. PCB drawing of sensor set up

Experimental procedure

For experimentation, PCB (Printed Circuit Board)was turned on such a way that it could give each and every reading of temperature and relative humidity while adjusting flow rates of dehumidified air and water flow.

De-humidifier with compressor was run before starting the experiment in order to get the desired relative humidity value and temperature of air. It is adjusted and kept constant at the level of the maximum water flow rate to be absorbed. The experiment were carried out with four different water flow rates, 25 cm^3/sec, 35 cm^3/sec, 45 cm^3/sec and 55 cm^3/sec whereas the dry air flow rate at 20^0C and 20% RH was maintained at 36 cm^3/sec. Trial was conducted at the ambient condition of 25^0C and 58% RH. The grinding temperature was elevated up to the 40^0C before experiment starts. The first samples were undergone conventional grinding and other three samples were undergone EWC samples with three different atomized water spraying as stated above. After grinding samples were allowed to cool down for two hours at room temperature and sealed with 300 micron gauge until HPLC analysis starts.

Laboratory testing procedure for quality analysis

Extracting Capsaicin Oleoresin

The extraction, using the method of Collins *et.al* (1995) and Zeid Abdullah Al Othman *et.al* (2011) with slight modifications was undergone . For capsaicinoid extraction, each powder samples (5g d.b) was placed in ethanol 50 ml in a 120 ml glass bottle equipped with a Teflon lined lid. Bottles were caped and placed in a water bath at 80^0C for 4hours, then swirled manually every hour. Samples were removed from the water bath and cooled to room temperature. Each supernatant layer of samples (50ml) was filtered through 0.45μm filter paper into a HPLC (model: DIONEX Ultimate3000) sample vial capped and stored at 5^0C until analysed.

Figure 7. HPLC analyser

High Liquid Chromotographic Analysis (HPLC)

HPLC operating conditions to determine total heat units (designated sort run) included ambient temperature, a flow rate of 1 $ml.min^{-1}$ and a run duration of 7 min. The mobile phase was isocratic with 70% solvent B(100% methanol) and 30% solvent A (10% methanol) (by volume) in water. For individual capsaicin peak detection (designated long run) operating condition included ambient temperature, a flow rate of 1 $ml.min^{-1}$ and a run duration of 20 min. The mobile phase was gradient consisting of 57% solvent B and 43 % solvent A for 10 min allowed by 68% solvent B and 32% solvent A for an additional 10 min.

Capsainoid Standards. Standard of 8 methyl-n-vanillyl – nonenamide(capsaicin) was obtained from Sigma-Aldrich INC., USA and was used for retention time verification and instrument calibrations of 300, 250, 200, 150, 100 and 50 ppm were prepared in 100% methanol by dilusion of a 1000 ppm stock solution. The standard solutions were run on the HPLC and the obtained standard curve plots of peak area against concetration are shown on Figure 10.

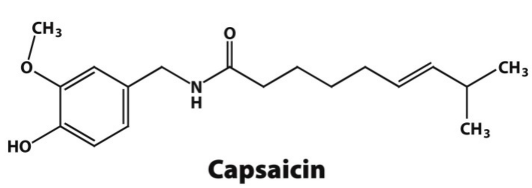


Figure 8. Structure of capsaicin

Figure 9. Capsaicin Standard from Sigma-Aldrich INC., USA

Compounds known as capsaicinoids cause the spicy flavor (pungency) of chili pepper fruit. Theprimary capsaicinoid in chili pepper is capsaicin, followed by dihydrocapsaicin, nordihydrocapsaicin,homodihydrocapsaicin and homocapsaicin. Capsaicin and dihydrocapsaicin account for approximately 90% of capsaicinoids in chili pepper fruit, are the two most potent capsaicinoids and their moleculesdiffer only in the saturation of the acyl group (Bernal, M.A, *et.al,* 1993). Therefore, for this study Capsaicinoid was selected for analyzing quality attribute during grinding.

Aparatus. Reverse Phase Chromatographic column is C_{18} (dimension 100x5 mm) from GERMANY. Its absorbent detector and Fluorescent Detector were set at 280nm and 280nm emission at 338.

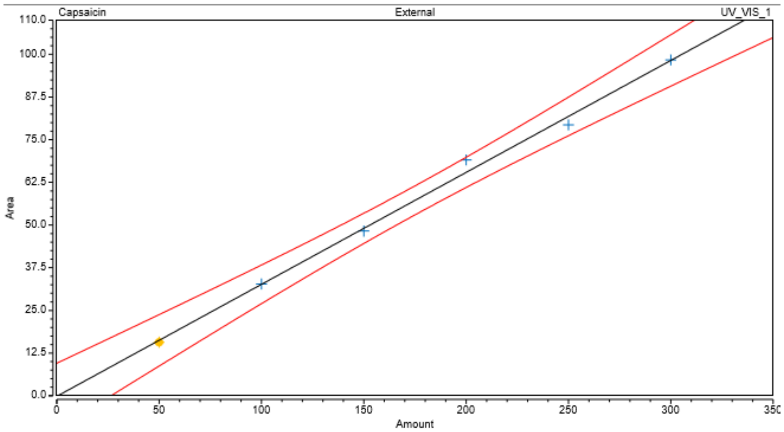


Figure 10. Calibration Curve for Capsaicin taken from HPLC

Analyzing Moisture Content of Final samples

It is unable to use the oven dry method to calculate the moisture content of chili powder, because when chili gets heated more than 120^0C, volatile compounds will be removed as the capsaicin melting point is 65^0C. Hence Dean and Stark apparatus was used. In a Dean and Stark method, representative chili sample (50g) was mixed with 100ml of toluene in 500ml glassware. The heating of the mixture was carried out above boiling temperature for six hours. Extracted moisture volume on toluene layer was measured using measuring cylinders. Then moisture content was calculated by using following equation (AOAC, 2000).

$$M_c = \frac{M_v \times D_w}{S_w} \times 100$$

Where,
Mc =Moisture content
Wv =Water volume
Dw =Density of water
Sw =Sample weight

Analyzing water activity

Water activity, not moisture content, predicts safety and stability with respect to microbial growth, chemical and biochemical reaction rates, and physical properties. Water activity (ISO21807) represents the energy status of water in a system. It is equal to the relative humidity of the air in equilibrium with a sample in a sealed chamber. Controlling water activity in spices maintains proper product structure, texture, and stability, density, and rehydration properties. Itis defined as the vapor pressure of water in a sample divided by the vapor pressure of pure water at the sample temperature. It is easily measured using highly accurate instrumentation called water activity meter (Model: *Labstart-aw*).The lower limit for all microorganisms is 0.60aw(Beuchat, L. R.,1981: Muggeridge, M. and M. Clay.,2001: Peter, K. V.,2001).

Analysing color value of final products

Surface color was determined using HunterLab (HunterLab – LabScan XE, Hunter Associates Laboratory Inc., Reston, VA, www. hunterlab.com), which includes lightness and chroma saturation. The Hunter L, a, b color space is a 3 dimensional rectangular color space based on the opponent – colors theory. For the L value which is “L “(Lightness) axis, 0 value is black and 100 is regarded as white. Similarly for “a” (red-green) axis, positive values are red, negative values are green and 0 is neutral. And for “b” (blue-yellow) axis, positive values are yellow, negative values are blue and 0 is neutral. After obtaining the sample from the grinder in different treatment the L*a*b* values were tested.

Specific Energy Consumption

The energy consumed in grinding per unit mass is important because too much finer may not be advised as it may not allow easy movement of the intake in the human intestine and too big particle size of the ground seed may not be desirable as it may reduced the bioavailability of the constituents (Meghwal, M. and T.K. Goswami,2013). The Specific energy is the amount of energy required to grind per unit mass of the ground seed which is represented by $kJkg^{-1}$.The electric current used by the machine during the grinding operation was measured by clip-on ampere meter (KYORITSU, Model 2608A). It was assumed that line voltage was 230 V and consumed power by the machine was calculated using following equation.

$$P = \frac{VI(W) x\ 3.6}{Feed\ Rate(kg/h)} \quad (17)$$

Where;

P = Power

V =Voltage

I = Ampere

Statistical analysis

The experimental structure of all the experiments was complete randomized design. Data gathered were analyzed using Analysis of Variance (ANOVA) by Statistical Analysis System (Annon, 2000). Percentage data were transformed to arc sin values prior to analysis. Differences between treatment means were obtained by Duncan’s multiple range test at 5% significance level ($p<0.05$).

IV. RESULTS AND DISCUSSION

The experiments on grinding of chilli were conducted five different conditions while some parameters were tested for whole cilli and a random market sample. One treatment on conventional grinding whereas other three treatments on EWC condition with three different water rates which were selected closer to the calculated water flow rate value. Using data acquisition system, temperature during grinding was monitored. After that collected samples were undergone for measuring moisture content, color observation and HPLC-Capsaicin analysis. Before carrying out the capsaicin extraction, samples prepared with ethanol are shown in figure 11.

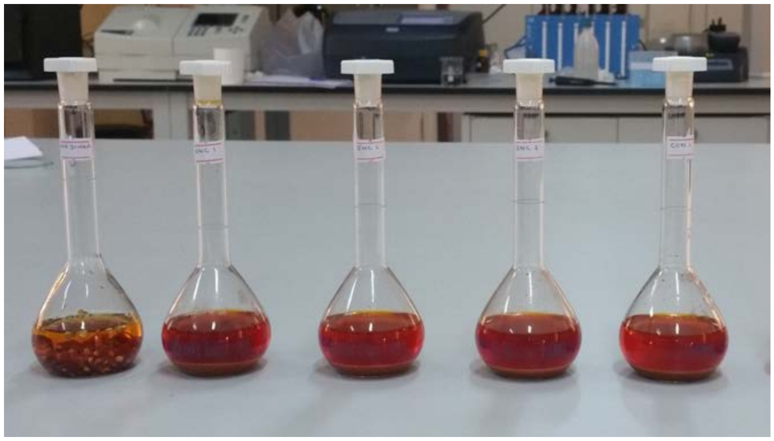


Figure 11. Sample prepared for extraction of Capcaicin

Table1. Effect of spraying water during grinding chilli compared to the conventionl grinding.

No.	Treatment	Treated water Quantity/ (cm3/sec)	Temperature increase during grinding/ (^{0}C)	Final Moisture content (%)	Capsaicin content/ (Peak area UV_VIS_1 ppm)	Water Activity	Color value (Hue L, a, b)	Energy Consumption /(kJ/kg)
1	CONVEN	non	4.67^a±0.58	5.87^d±0.3	128^c±3.0	0.52^c±.006	53.33±0.6, 16.01±0.9, 28.87±1.6	303.6
2	EWC 1	25	*10^b.00±1	7.1^d±0.2	133^c±12.5	0.53^b±0.01	51.62±0.2, 13.99±0.6, 26.01±1.2	303.6
3	EWC 2	35	*12.33^c±1.53	8.53^b±0.2	163^b±14.19	0.53^b±0.006	50.16±0.3, 14.40±0.1, 25.05±0.6	303.6
4	EWC 3	45	*13.33^c±1.53	9.4^a±0.5	136^c±8.02	0.57^a±0.01	50.16±0.3, 14.12±0.2, 25.09±0.1	303.6
6	EWC 4	55	The system stucked due to the excess water					
7	Whole	-	-	7.95±0.26	238^a±2.65	-	43.93± 0.4 16.12±0.210.12±0.3	-

*Temperature decreased during grinding and Any two means in the same column followed by different letters differ significantly according to Duncan's multiple range test (P<0.05).

This grinding trials were performed in a open space and done with chilli 500g lots. Grinding time for each trials took small durations in which all recorded within 60 seconds. Therefore, temperature changes were observed and changes are significant. The corelation between the temperature change respect to the sprayed water amount shown in figure 12 which is given similar linear pattern with R^2 equal to 0.986 what we obtained in mathematical derivation given in equation 14.

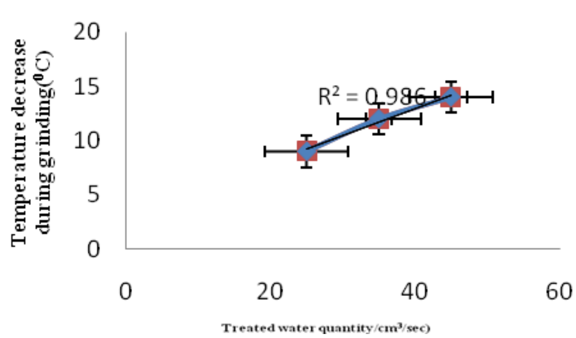
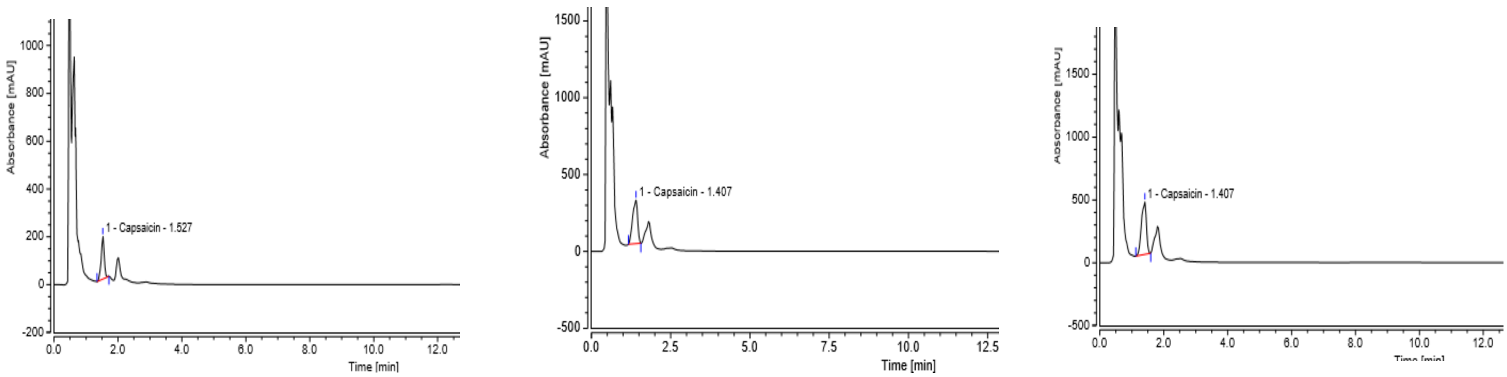


Figure 12.Treated water quantity vs. Temperature increase during grinding

Even though the results shows the decrease in temperature while increase in water amount, Capsaicin amount does not show same corelation. Maximum Capsaicin amount shows the water quatity in 35cm^3/sec which is closer to the theoretical amount which is 33cm^3/sec. However, the next increased amount 45cm^3/sec shows the reduction in Capsaicin, maybe it evaporates with water in fact the literature shows Capsaicinis insoluble in water at 25^{0}C . Anyway there is a significant difference for Capsaicin preservation in between conventional grinding and the second EWC grinding which is 15 % success. The comparison of Capsaicin content in between the conventional grinding and the EWC grinding respect to the Chili unground is shown in figure 13using the HPLC graphs.



(a) (b) (c)

Figure 13.Chromatogram Results of (a) Conventional (b) EWC 2 (c) Chili unground

According to the Hue angle, conventional grinding sample is the most closer to the orange color with the highest lightness value than the others. Second and third EWC samples possess in darker red zone with lower lightness value. It means EWC samples tend to become red color than the conventional grinding sample as the matter of fact that the Capsaicin which is higher in EWC grinding is red in native color.

In the present study, Specific energy consumption results of different conditions of EWC and conventional grinding doesn't show any difference among each other. The power requirement, size of the ground particle and increase in the total surface area are the functions of initial size, material nature, strength of the particle, shape, hardness, smoothness, brittleness, stickiness and moisture content. Therefore, it can be imagined that external addition of water to the chili before grinding couldn't affect the grinding properties which are stated above.

V. CONCLUSION

This study could be concluded that Evaporative Water cooling (EWC) Grinding is a successful new grinding method for controlling temperature during griding while preserving the aroma quality of spices without retention of excess water in the final product. According to the feeding rate of product fed into the grinder, necessary water flow rate and dry air flow rate must be calculated before introducing this method in spice processing.

REFERANCES

[1] Annon, (2000). SAS Institute Inc.,SAS User's Guide: Statistics. SAS Institute Inc. Cary, NC, 2000

[2] Bernal, M.A.; Calderon, A.A.; Pedreno, M.A.; Muñoz, R.; Ros Barceló, A.; Merino de Caceres, F. Capsaicin oxidation by peroxidase from Capsicum annuum (variety Annuum) fruits. J. Agric. Food Chem. 1993, 41, 1041-1044.

[3] Beuchat, L. R. "Microbial stability as affected by water activity." Cereal Foods World 26.7 (1981): 345-49.

[4] Crop Protection Handbook Volume 100, Meister Media Worldwide, Willoughby, OH 2014, p. 156

[5] E. Block, Antithrombotic agent of garlic: A lesson from 5000 years of Folk medicine. In: Folk medicine, the art and the science, 1986,pp125 – 137.

[6] Horwitz,W., Official Method of Analysis of AOAC International, Vol. II, Suite 500 481, Maryland 20877-2417. USA., 2000

[7] https://pubchem.ncbi.nlm.nih.gov/compound/Capsaicin#section=Top National Center for Biotechnology Information, U.S. National Library of Medicine 8600 Rockville Pike, Bethesda MD, 20894 USA.

[8] J.S Pruthi, Spice and condiments –chemistry, microbiology and technology. Academic press. New York, 1980, pp1-450.

[9] K.K. Singh, and T.K.Goswami, Design of a Cryogenic grinding system for spices, of food engineering , 1998,39:pp 359 -368.

[10] K.M Sahay and K.K Singh, Unit Operation in Agricultural processing, Vikas Publishing House Pvt. Ltd, 2004, pp 233-235.

[11] Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 12th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2012.,p p. 849.

[12] M. Viuda –Martos, Y. Ruiz – Navajas, J. Fernandez – lopez, and P J.A. erez – Alvares, spice as functional foods critical reviews in food science and nutrition,2011, pp 51:13-28.

[13] M.Meghwal, T.K Goswami, Cryogenic grinding of spices is a novel approaches whereas ambient grinding needs improvement, journal of food science and technology, 2010, pp 4:24-37.

[14] Meghwal, M. and T.K. Goswami, Ambient and Cryogenic Grinding of Fenugreek and Flow Characterization of Its Powder. Journal of Food Process Engineering, 2013. 36(4): p. 548-557.

[15] Muggeridge, M. and M. Clay. "Introduction." Handbook of Herbs and Spices. Ed. K. V. Peter. 1st ed. Cambridge, England: Woodhead Publishing Limited, 2001. 13-21.

[16] Peter, K. V. "Introduction." Handbook of Herbs and Spices. Ed. K. V. Peter. 1st ed. Cambridge, England: Woodhead Publishing Limited, 2001. 1-12.

[17] R.L Earle, Unit Operation in Food Processing,Second Edition, Pergamon Press,Oxford.New York, Seoul. Tokyo,1992,pp159-165

[18] S.M Henderson and R.L Perry,Agricultural Process Engineering, The AVI Publishing Company, Inc., USA,1976, pp 130-149

[19] Singh, S., (2003). Electric Engineering Drawing. part II,.S.K,. Kataria and sons, p 156

AUTHORS

First Author – Eng. D.M.S.P Bandara, BSc Engineering (Peradeniya), MEng (Moratuwa), CEng, MIESL, Mechanical Engineer, Institute of Post Harvest Technology, Sri Lanka.srimapriyangika@yahoo.com
+94 718025200

Second Author – Dr. K.S.P Amaratunge, BSc (Agric), M(Agric), Ph.D (Kyushu Japan), Department Of Agriculture Engineering, University of Peradeniya, Sr Lanka. sanath.amaratunga@gmail.com

Third Author – Eng. T.M.R Dissanayake, BSc Engineering (Peradeniya), MEng (India), CEng, MIESL, Institute of Post Harvest Technology, Sri Lanka mrdissanayake@yahoo.com

Fourth Author – Mr. C.R Gunawardana, BSc (Sp-Chemistry), Institute of Post Harvest Technology, Sri Lanka, crohan74@gmail.com

Correspondence Author – Eng. D.M.S.P Bandara,srimapriyangika@yahoo.com, srimabandara2013@gmail.com,