

DEVELOPMENT OF OHMIC HEATING MODEL FOR PARBOILING OF PADDY

ABSTRACT:

Ohmic heating is an alternative and fast technology for processing of food products, which takes its name from Ohm's law. The basic principle of this technique is the conversion of electrical energy into heat, resulting in internal heat generation with in the food products eg- Paddy. The aim of the study is to develop an ohmic heating model for parboiling of paddy. In this study the voltage is applied directly to the end of both electrodes from an electrical source which cause internal energy generation into the food material, like- paddy. This technology has wide range of applications in the area of food processing. In the present study, a laboratory scale ohmic heater was developed for the parboiling of paddy.

Keywords: *Ohmic heating, Electrode, Paddy, Parboiling, Voltage, Electrical conductivity.*

INTRODUCTION:

Paddy (*Oryza sativa L.*) is an important food crop of India and second most important crop of the world. In India, rice processing is the oldest and the largest agro processing industry. At present it has a turnover of more than Rs. 36,500 crores per annum. India processes about 85 million tonnes of paddy per year and provides staple food grain and other valuable products required by the population. Recently, more than 50 % of the overall rice production is processed by modern mills, 40 % by conventional mills, and the remaining 10 % by hand pounding. Cost of production is an important variable that influences the profits, which are also an indicator of management efficiency. Over years in country, many rice processing units have to be closed down. The main reason for closure is higher costs and lower net returns. The modern mills are operated by adopting new technology and the recovery

31 percent of head rice is more compared to the conventional units. In the case of
32 conventional milling units, the age old technology has resulted in higher percentage
33 of broken, which yield less return [1].

34 **Parboiled rice** (also called converted rice) is the rice made from milling of
35 partially boiled paddy. Paddy parboiling process is an old practice. The three basic
36 steps of parboiling are soaking, steaming and drying. This technique yields easy
37 milling as well as reduced breakage during milling. The processes involve soaking
38 the paddy in hot water usually at around 70 °C for 10 to 24 hours in order to saturate
39 the paddy with moisture. The soaked paddy is then steam heated till they are
40 gelatinized. They are then dried and milled [2].

41 Khadi & Village Industries Commission, project profile for raw & parboiled rice
42 mill gives the information about investment on plant and machinery for raw rice in the
43 milling section 57 lakhs and excise duty & other taxes is 9 lakhs; total investment on
44 raw rice project is 66 lakhs, and for parboiled rice project total investment is Rs.120
45 lakhs which includes 54 lakhs in milling section, 33 lakhs in steam plant, 17 lakhs in
46 steam boiler and 16 lakhs in excise duty & other taxes [3].

47 In the traditional parboiling plant, heating of soaked paddy is carried out in
48 parboiling tank by direct injection of steam generated in the steam boiler which is
49 fitted outside the rice mill in utility section. Boiler unit consists of boiler, fuel tank,
50 water tank, water supply, insulated piping from boiler up to parboiling tank [3]. The
51 entire boiler unit needs separate care and for this purpose a certified boiler operator
52 with helper needs to be maintained and paid throughout the year, which adds to the
53 processing cost of parboiling rice. If this heating system may be change from
54 traditional steam heating with ohmic heating system, then it will be possible to simply
55 attach two electrodes on the two opposite faces of parboiling tank which will help in
56 resistance/ohmic heating of entire mass of paddy soaked in water housed inside the
57 parboiling tank. Desired temperature can be generated in desired time by applying
58 the recommended voltage for the given distance between two electrodes [4].

59 In 1827, Georg Ohm, was the first to outline which is known as Ohm's law but
60 recognition of the thermal effects of electricity within a conductor was the first
61 elucidated by James Prescott Joule in 1840. The technology was once again revived
62 in the 1980 and some industrial applications have resulted, including pasteurization
63 of liquid eggs and processing of fruit products, among others. Ohmic heating concept

64 was used in the early 20th century where electric pasteurization of milk and other
65 food materials were achieved by pumping the fluid between plates with a voltage
66 difference between them [5].

67 Ohmic heating is a resistance heating technique for liquids and pumpable
68 particles [6]. It consists of equipment for passing alternative current through the fluid
69 between electrodes. Ohmic heating is used in a wide range of applications such as
70 pasteurization, sterilization, preheating, blanching [7].

71 This is one of the excellent alternative methods of heating, this technique
72 shows much promise especially in food industry over the last few decades, because
73 there is an increasing shift from batch thermal operation towards continuous high
74 temperature and short time processing of foods [8].

75 This technique involves several advantages like heating of food material by
76 internal heat generation without the limitation of conventional heat transfer and some
77 of the non-uniformity commonly associated with microwave heating due to limited
78 dielectric penetration. Heating takes place volumetrically and the product does not
79 experience a large temperature gradient within itself as it heats. Higher temperature
80 in particulates than liquid can be achieved which is impossible for conventional
81 heating, reducing risks of fouling on heat transfer surface and burning of food
82 product, resulting in minimal mechanical damage and better nutrient and vitamin
83 retention [9]. It has high energy efficiency because 90% of electrical energy is
84 converted into heat.

85 The method optimizes capital investment and product safety as a result of
86 high solids loading capacity. Its process control is fairly easy due to instant switch-on
87 and shut down. Since it does not contain moving parts, the maintenance cost is low.
88 The system can be stored and distributed in ambient temperature when confined
89 with an aseptic filling system. It does not create any noise and is environment
90 friendly [10]. Similarly, ohmic heating was found to be more efficient for the required
91 microbial and pectin esterase inactivation due to a shorter residence time while
92 released flavour compounds were not degraded as quickly as during conventional
93 pasteurization [11].

94

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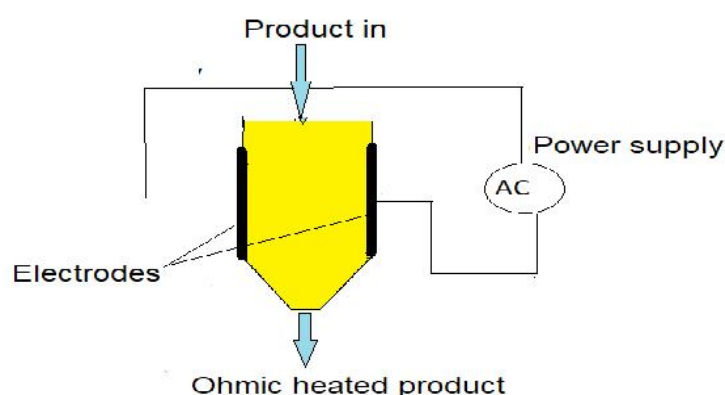
96 **PRINCIPLE:**

97 An ohmic heater is an electrical heating device that uses a liquid's own
 98 electrical resistance to generate the heat. Ohmic heating works on the principle of
 99 Ohm's law of electricity. The passage of electric current through an electricity
 100 conductive food material obeys Ohm's law and heat is generated due to electrical
 101 resistance of food [12].

102
$$V \propto I$$

103
$$V = IR \quad \dots\dots\dots\text{eq. 1}$$

104 Where, V = Voltage (volt),
 105 I = Current (ampere),
 106 R = Resistance (Ohm).



107
 108 **Fig. 1 - The principle of ohmic heating**

109 **MATERIAL AND MATHODS:**

110 **A- Development of ohmic heating model:**

111 For development of an ohmic heating model for parboiling of paddy with the
 112 help of ohmic heating setup. The following factor which are used in to develop an
 113 ohmic heating model for parboiling of paddy. The following parameters for designing
 114 of the model are given as below:

115 **1.) Chamber of Ohmic heater:**

116 The selection of suitable material for an ohmic heating chamber is most
 117 important for efficient heating and also for purpose of safety during the operation of

ohmic heater. The constructive material of ohmic heating chamber should be fully insulated, it should be able to withstand higher temperature, it should be chemically inert and it should not affect the quality of the material, it should be light in weight and easily available in the market at reasonable cost [13]. On the basis of these factors ohmic heating chamber can be constructed by perspex sheet, CPVC pipe, PVC end cap, electrodes and plywood etc. Considering all the important factors CPVC pipe of 18.2 cm length, 4.35 cm diameter and 10.5 mm thickness has been selected for construction of the ohmic heating chamber. The cylindrical ohmic heating chamber has advantage of minimum heat loss than square and rectangular chamber and it also avoids the leakage of water from the cylinder in the absence of any joints or fitting in the chamber. The size of ohmic heating chamber will be decided on the basis of volume and density of the paddy and water. The sample of paddy and water were mixed of 100gm paddy with the sufficient amount of water (1:1.6 as per recommendation of experimental design) and used to investigate the capacity of an ohmic heating chamber.



Fig. 2. Ohmic heating chamber for paddy.

2.) Temperature controller and sensor:

LOS made digital temperature controller with copper probe was used to monitor the temperature inside the heating chamber. The copper coated (PT-100) I type temperature sensor can sense the temperature of 0-800 °C is placed at the center of the heating chamber to control the temperature during ohmic heating [14].



Fig. 3. Temperature controller and sensor for ohmic heating system.

3.) Electrode:

The selection of electrode is most important factor for designing of an ohmic heating system for processing of food products. There are many types of conductive materials are available in the market such as titanium, stainless steel, aluminium and graphite, the selection of the conductive material on the basis of price and accuracy. The availability and correction resistance which may affect the efficiency of an ohmic heater [15]. The electrode should be good grade, non-corrosive, chemically inert and should provide smooth finish [16]. Considering these factors stainless steel (SS), rod with 14mm diameter and 75mm length was selected as electrode material because of its accuracy and suitability are good for food products. The distance between two electrodes has been kept as 9cm to pass maximum voltage gradient of 26.11 V/cm from Indian domestic supply of 235V.



Fig. 4. Electrode using in ohmic heating model for parboiling of paddy.

4.) Multi-function meter:

The multi-function meter was used in ohmic heating system for monitoring the input voltage, ampere and frequency (Hz.) of the current and it is directly connected to the main source of the current and display all readings time to time during the processing of material. It is placed on the right side of the ohmic heating system.



Fig. 5. Multi-function meter for ohmic heating system.

5.) Power supply:

The single phase power supply from alternating current (AC) mains (235 V, 50 Hz) was used in the experimental set-up. A constant voltage stabilizer is used before the autotransformer to control voltage functions. The electrical variables were recorded using digital multi-function meter (ampere, voltage and frequency). Important parameters in the designing of the power supply system were personal safety and equipment safety to avoid accidents during ohmic heating.

6.) Wooden platform, Box and stand:

The wooden platform of ohmic heating system having 61cm width and 61cm length for supporting the whole ohmic heating system or also for supporting of metal stand having 26cm height including with 10cm clamp for holding the heating chamber of ohmic heating system, and the hollow wooden box was used in ohmic heating system for holding the multi-function meter or temperature controller. The geometrical information of the wooden box, it's have 61cm width, 61cm height and 14cm thickness of this box.

B- Determination of heating characteristics:

There are some important heating characteristics like heating power, heating rate, electrical conductivity and energy efficiency that must be continuously monitored and determined during the ohmic heating process for parboiling of paddy, that are given as below.

1.) Heating power (P):

The energy (P) given to the ohmic heater at a given temperature can be calculated by using the current (I) and voltage (V) values during heating time (Δt). It can be calculated by equation given below [17].

$$P = \Sigma VI \Delta t \quad \text{.....eq. 2}$$

Where, P is the heating power (Energy)
V is Voltage
I is Current
 Δt is Heating time.

2.) Heating rate (Q):

Electrical current passed through the material to be heated can cause generation of sensible heat in to the material, due to which the temperature of the material can rise from initial temperature (T_i) to final temperature (T_f). Therefore, the amount of heat given to the system can be calculated from the following equation [18].

$$Q = m C_p (T_f - T_i) \quad \text{.....eq. 3}$$

Where, Q is Heating rate
 T_i is initial temperature
 T_f is final temperature.

3.) Electrical conductivity:

It is quantity of electrical energy transferred through a unit area, per unit potential gradient and per unit time. The electrical conductivities of samples were calculated from the voltage and current data using the following equation,

$$\sigma = L / A \times I / V \quad \text{.....eq. 4}$$

Where, σ is the electrical conductivity (S/cm)
L is the distance between electrodes (cm)
A is the area (cm^2)
I is an alternating current passing through the sample (Amp)
V is the voltage across the sample (V)

Electrical conductivity is an important parameter for ohmic treatment of food products. Rate of ohmic heating depends on the electrical conductivity of the food products during process [19].

4.) Energy efficiency (ϵ):

Energy efficiency is used to evaluate the performance of an ohmic heating

218 system. It is defined as the ratio of total energy utilized to heat the sample to total
219 input energy and it can be calculated by following equation [20].

$$\text{Energy efficiency} = \frac{\text{Energy utilized to heat the sample}}{\text{Total input energy}}$$

$$\epsilon = m C_o (T_f - T_i) / \sum VI \Delta t \quad \dots\dots\dots \text{eq. 5}$$

222 **RESULT AND DISSCUSSIONS:**

223 Ohmic heating technology is the most important technology for the research
224 purpose, professionalism and widely used for food processing industries because of
225 its advantages over conventional heating technology. Researchers and food
226 processing industries found superior quality product with minimal nutritional or quality
227 degradation after using the ohmic heating technology. Its allow uniform and fast
228 heating, simple process and designing of ohmic heater is also relatively a simple
229 task. For the development of an ohmic heating device was done by using conductive
230 material like electrode which was made by stainless steel and the electrodes are
231 directly contact with the food material, eg. Paddy, and CPVC pipe for the ohmic
232 heating chamber are shown in Fig. 6. The volume of the ohmic heating chamber was
233 decided on the basis of volume of paddy and water fed to the heating chamber.



234
235 **Fig. 6. Ohmic heating setup for parboiling of paddy.**

236 **1.) Volume of cylinder:**

237 The cylinder was used in ohmic heating system in the form of an ohmic

heating chamber for parboiling of paddy by ohmic heating. The volume of the cylinder can be measured by the given formula.

$$\text{Volume of Cylinder} = \pi r^2 h \quad \dots\dots\dots \text{eq. 6}$$

Where, r = Radius of the cylinder

h = Height of the cylinder.

$$\pi = 22/7 \text{ (3.14)}.$$

For measuring of the volume of an ohmic heating chamber, some geometric data are available for calculating the volume, height of the pipe is 18.2cm and the diameter of the pipe is 4.35cm.

$$\text{Volume of the cylinder (V)} = \pi r^2 h$$

$$V = 3.14 \times (2.175)^2 \times 18.2$$

$$\mathbf{V = 270.35 \text{ cm}^3}$$

2.) Capacity of the heating chamber:

Capacity of an ohmic heating system refers to the weight of sample (paddy and water) fed into the chamber per unit time. The heating chamber with cylindrical geometry was finalized to construct in order to avoid leakage of paddy and water from the system. Following parameter were recorded and used to construct the ohmic heating chamber;

Weight of the paddy taken = 100g

Paddy and water ratio = 1:1.6

Volume of chamber = 270.35 cm^3

Weight of total sample = 260g

Time taken = 18min

$$\text{Capacity} = \frac{\text{weight of the sample}}{\text{Time taken}} \text{ kg/hr} \quad \dots\dots\dots \text{eq. 7}$$

$$= \frac{(260 \times 60)}{(18 \times 1000)} = \mathbf{0.86 \text{ kg/hr}}$$

The capacity of ohmic heating chamber as tested for parboiling of paddy as found to be 0.86kg/hr.

SUMMARY AND CONCLUSIONS:

The designed laboratory model of ohmic heating showed excellent performance during parboiling of paddy. In this system the paddy was heated from 35°C to 95°C in 15min a voltage gradient of 26.11V/cm. The heating was uniform for all purposes. Boiling and soaking of paddy during ohmic heating should be given serious attention. The ohmic heating is a fast growing technology in the food process industries. It allows for the best quality production in the food industries.

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