Curriculum Vitae

Ajitkumar Sudhakar Gudekar

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Academic Qualifications

- **Ph. D.(Tech.) in Chemical Engineering (2009)**

  Chemical Engineering Department, Institute of Chemical Technology, Mumbai.

  Thesis : Optimization of Concentrating Type Solar Collector and other Thermal Systems
  Supervisor : Professor A. B. Pandit

- **Master of Chemical Engineering (2002)- First class with 'A' grade for Thesis.**
  Chemical Engineering Department, Institute of Chemical Technology, Mumbai.

  Thesis : Engineering Aspects of Manufacturing Non-cyclic Esters of Phosphoric Acid
  Supervisor : Professor B. N. Thorat

- **B.E. (Chemical) (2000)- Second class with 57 %.**
  D. J. Sanghvi College of Engineering, Vile Parle, Mumbai.

  Project : Manufacturing of 1000 TPA Adipic Acid

Professional Qualification

NPC (National Productivity Council) **Certified Energy Auditor (EA- 13239).**

Professional Skills and Experience

Design, Testing, Techno-Economic analysis, Teaching, Training.

Work Experience (Total: More than 11 years, of which, 10 years is post PhD)

1. Presently working as **Assistant Professor** at **'D. J. Sanghvi College of Engineering'** (Chemical Engg. Dept.), Vile Parle, Mumbai (since July 2015).

2. **'Institute of Chemical Technology', (formerly UDCT)**, Mumbai, as **Post-Doctoral Research Associate** (Jan 2014 to July 2015)
   - Solar Energy- High temperature concentrator development for Industrial Process Heat (IPH) applications.
   - Energy conservation in Cooking- Technology development, testing, demonstration, implementation.

3. '**Waaree Energies Pvt. Ltd.',** Mumbai as **Sr. Manager- Solar Applications** (Sep 2012 to Nov 2013)

- Solar desalination.
- Solar air conditioning.
- Solar heating applications.

4. '**Flareum Technologies' (formerly, Gadhia Solar Energy Systems)**, Valsad, Gujarat as **Manager- R&D** (Feb 2012 to Sep 2012)

- Performance evaluation of Solar steam generation system (Scheffler dish).
- Solar thermal system configurations for various applications- steam/ hot water, air conditioning, cold storage.
- Development of solar dryer.
- Solar energy based cooking system development.

5. '**Land Research Institute**', Mumbai as **Post-Doctoral Research Associate** (July 2009 to Feb 2012)

- Solar energy: Solar energy based steam generation systems and Solar dryers.
- Energy Conservation in Cooking: R&D and commercialization of energy efficient cooking devices.
- Design and development of large scale energy efficient continuous cooking systems.
- Design and development of biomass based energy efficient cooking stove.

6. '**Laxmi Organic Industries Limited**', (MIDC Mahad, Maharashtra), as **Trainee Project Engineer** (July 2002 – March 2004)

- Recovery of Acetic acid from vent gases: Loss quantification and Pilot Plant study; Acid recovery in the form of Sodium Acetate.
- Recovery of Acetic acid from aqueous waste stream.
- Dilute Acid Up-gradation: Separation of formic acid using Ion Exchange Resins

Recognition and Technology dissemination

1. First prize for CPC based Solar steam generation system at KAIF (Knowledge and Innovation Fair) 2009, National level competition organized by TATA Power, Mumbai.
2. Technology for Energy efficient cooking device- Eco-cooker now licensed to Ecosense Appliances Pvt. Ltd. (Aurangabad, Maharashtra) and product is now commercially available.

Publications

- **A. S. Gudekar**, A. S. Jadhav, S. V. Panse, J. B. Joshi and A.B. Pandit. 'Cost Effective Design of Compound Parabolic Collector for Steam Generation'. *Solar Energy,* Vol. 90 (2013) pp 43–50.
- A. S. Jadhav, **A. S. Gudekar,** R. G. Patil, D. M. Kale, S. V. Panse and J. B. Joshi, 'Performance analysis of Novel and Cost Effective Compound Parabolic Collector'. *Energy Conversion and Management* Vol. 66. (2013) pp 56-65.
- S. V. Panse, A. S. Jadhav, **A. S. Gudekar** and J B Joshi, 'Inclined Solar Chimney for Power Production'. *Energy Conversion and Management,* Vol. 52 (2011) pp. 3096-3102.
- A. A. Ganguli, **A. S. Gudekar**, A. B. Pandit and J. B. Joshi, 'A Procedure to Improve the Energy Efficiency of a Cooking Device via Thermal Insulation'. *The Canadian Journal of Chemical Engineering,* Vol. 90 (2012) pp. 1212–1223.

- J. B. Joshi, A. B. Pandit, S. B. Patel, R. S. Singhal, G. K. Bhide, K. V. Mariwala, B. A. Devidayal, S. P. Danao, **A. S. Gudekar**, and Y. H. Shinde, 'Development of Efficient Designs of Cooking Systems - I: Experimental'. *Ind. Eng. Chem. Res.*, 2012, *51* (4), pp 1878–1896.
- J. B. Joshi, A. B. Pandit, S. B. Patel, R. S. Singhal, G. K. Bhide, K. V. Mariwala, B. A. Devidayal, S. P. Danao, A. A. Ganguli, **A. S. Gudekar**, P. V. Chavan, and Y. H. Shinde, 'Development of Efficient Designs of Cooking Systems - II: Computational Fluid Dynamics and Optimisation'. *Ind. Eng. Chem. Res.*, 2012, *51* (4), pp 1897–1922.
- R. S. Singhal, A. B. Pandit, J. B. Joshi, S. B. Patel, S. P. Danao, Y. H. Shinde, **A. S. Gudekar**, N. P. Bineesh, and K. M. Tarade, 'Development of Efficient Designs of Cooking Systems–III: Kinetics of Cooking and Quality of Cooked Food Including Nutrients, Anti-nutrients, Taste and Flavour. *Ind. Eng. Chem. Res.*, 2012, *51* (4), pp 1923–1937.

Conference presentations

- S. S. Waje, **A. S. Gudekar**, B. N. Thorat and A. Mehta: **'**Engineering Aspects of Manufacturing Tri n-Butyl Phosphate Ester', at '**ISCRE-18**' (International Symposium in Chemical Reaction Engineering), Chicago, US, June 2004.
- S. V. Panse, **A. S. Gudekar**, A. S. Jadhav and J. B. Joshi: 'Compound Parabolic Solar Collector for Process Heat', at '**International Conference on Solar Process Heat (World Sustainable Energy Days 2011)**', Wels, Austria, March, 2011.
- **A. S. Gudekar**, 'Solar Energy based Continuous Cooker', presentation at '**6th SCI World Conference, 2017**', Muni Seva Ashram, Vadodara, Gujarat, January 2017.

Computer Skills

1. Windows based processing, Microsoft Word, Excel and PowerPoint.
2. Programming in C and Fortran- Basic level.
3. CFD: ANSYS Workbench for Fluid flow and Heat Transfer analysis- Basic level.
4. HTRI educational version- Software for heat exchanger analysis and design.

Personnel Details

Date of Birth : 7th June, 1978
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Marital Status : Married

References

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Salient features of Research work

Research Topic: Optimization of Concentrating Type Solar Collector and other Thermal Systems

A. Steam Generation using Solar Energy

A PTC system of 5 m^2 aperture was fabricated and tested for steam generation. Major portion of industrial heat requirement falls in the medium temperature range (< 200^oC). CPC systems (Compound Parabolic Collector) systems having advantage of no or minimal tracking can be used for this purpose. Various designs of CPC were fabricated and tested for thermal efficiency with water as a heat transfer fluid. A final system having 100 m^2 aperture area was designed, fabricated and tested successfully for steam generation up to temperatures of 120 ^oC. It was possible to reduce the cost for steam generation substantially compared to PTC. The steam generated using this CPC system was used for applications like Ammonia Absorption Refrigeration, Continuous Cooking of rice.

B. Scheffler Dish Standardization

Scheffler dish is used as a solar concentrating device for steam generation at low temperatures especially for cooking purposes. A procedure was developed to find out the optical efficiency of the concentrator at the focal point which involved ray tracing technique for various parts of the dish. Correcting measures for the system were applied to improve the thermal efficiency after secondary reflector. Also, this dish was used to provide the energy required for cooking of food items in energy efficient cooking device, Ecocooker.

C. Inclined Solar Chimney for Power/ Drying Applications

The present concept of solar chimney has concerns about stability and economic viability of the chimney and also demands elaborate engineering techniques for constructing a tall chimney. Various geometries of ‘‘Inclined Solar Chimney’’ (ISC) were studied in lab and in actual solar conditions for testing air temperature and velocity. In this concept, chimney and the collector get merged. This makes the structure stable, cost effective and easy for construction. A mathematical model has been developed considering the total energy balance. With some design modifications, the ISC set-up can also be used for drying of various agricultural/food products for domestic/commercial applications.

D. Development of Energy Efficient cooking device- Ecocooker

Ecocooker, a device for efficient cooking uses simple principles to save energy. Performance of ecocooker was further enhanced by introducing flue gases between two covers of ecocooker and optimizing various parameters like heat flux and distance between burner and base. After incorporating changes, new design for existing capacity cooker was suggested, tested exhaustively and implemented. Various capacity models ranging from domestic (3.5/ 5 lit) to Community scale (120 lit) were designed. Many ecocookers have been already supplied across the state of Maharashtra and are in use with substantial fuel savings. This technology is now under commercial development by a company (EcoSense Appliances Pvt. Ltd., Maharashtra) with license from Institute of Chemical Technology (Matunga, Mumbai) and Land Research Institute (Fort, Mumbai).

E. Large Scale Cooking

Large scale cooking is used at many locations like community places, government mid-day meal schemes and food programs run by charitable institutions. Batch cooking processes have limitations in handling large food quantities. Hence, most promising option in such cases is of continuous cooking. Continuous cooking system of 20 kg/hr capacity was developed for cooking of rice, dal with horizontal jacketed screw design. Scaled up version of 300 kg/hr capacity is now being commercialized.

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Design and development of energy efficient continuous cooking system

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ABSTRACT

For large scale cooking, it is desirable to implement continuous cooking. In addition to the usual advantages of continuous cooking (size of cooker, uniform cooked quality, possibility of process control), there is a possibility of increasing the thermal efficiency by preheating water against the hot cooked food leaving the cooker. In the present work, solid and liquid phase residence time distribution (RTD) have been measured in 120 mm diameter and 1.6 m long continuous cooker. Three levels of screw speed (1, 3 and 5 rpm), two levels of solid flow rate (12and 24 kg/h) and three levels of liquid flow rate (15, 25 and 35 lph) were selected. The solid phase was always found to move in a plug flow manner as the minimum Peclet number was found to be 81.5. This information was found to be useful for deciding the capacity of the continuous cooker. Thus, the time required for batch cooking was found to be equal to the minimum residence time in a continuous cooker at equivalent operating condition of temperature.

1. Introduction

Large scale/community cooking has become a necessity at many places such as hostels, jails, industrial kitchens, religious places, and kitchens for preparing mid-day meals for school children. Hostels, jails and industrial kitchens prepare around 1000–2000 meals at a time. This scale increases to tens of thousands at religious places and for kitchens preparing mid-day meals. In the state of Maharashtra (India) alone about 50,000 such community kitchens are in existence and the number is estimated to be 100,000 in the country.

Though the scale of cooking is large at above mentioned places, the method of cooking has been largely traditional and practically independent of scale. The widely used method has been open pan cooking with thermal energy efficiency less than 20%. Further, this method is less hygienic, time consuming and involves a lot of wastage of resources like water and fuel. Various heating methods ranging from three-stone fires, biomass and gas stoves, electrical, microwave and induction ovens have been used over the years for cooking. Depending on the method used, the overall thermal efficiency may vary from 10% to 15% for traditional cooking, which can be increased up to 70% for thermally efficient cooking devices (Joshi et al., 2012a).

In developing countries, where 70% of the population resides in rural areas, open pan cooking method is still the most widely used process. Pressure cooker development has improved the thermal efficiency to a good extent. However, in view of safety, its size is limited to the cooking volume of about 10 l and rarely large size pressure cookers are used in practice, except in industrial food processing units. These days, steam is used for cooking, generated in industrial boilers or by using a renewable source like solar energy at many places. Steam use can be either, live (directly introduced in the food to be cooked) or as an external heating medium using a jacketed vessel.

There is an urgent need to employ an energy efficient engineering solution for preparing hygienic, nutritious meals on a large scale, which also has advantages of energy efficiency, ease of operation and efficient resource utilization. The better option for large scale cooking would be a continuous cooking process which offers a number of advantages over a batch process. Firstly, the batch processes offer less than 20% energy efficiency whereas in continuous process it exceeds 60%. Also, in continuous cooking process, the quality of cooked food can be kept uniform and under relatively better hygienic condition (untouched). Though large scale cooking is not uncommon, the continuous process is seldom employed in practice. In the recent past, various continuous methods for cooking of grains (especially rice) are being patented. These will be briefly described in the next section.

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Cost effective design of compound parabolic collector for steam generation

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Abstract

In this paper we present a working model of Compound Parabolic Collector (CPC) system for the application of process steam generation. It is easy for fabrication, operation and has a lower cost compared to other available concentrating solar collector systems with further possibility of lowering the cost. An experimental demonstration unit having an aperture area of nearly 30 m^2 was set up and tested for steam generation. The performance analysis of the system shows potential of improving thermal efficiency up to 71%. By virtue of its geometry, the proposed CPC system requires much lesser mirror area compared to conventional CPC design and require single tilt adjustment per day for a daily 6 h operation.

Keywords: Solar energy; Compound Parabolic Collector (CPC); Solar thermal system; Solar steam generation

1. Introduction

Though electricity is the highest quality of energy and should be given priority, energy consumption in the form of direct heat also forms a major mode of energy consumption. It is the most widely known form of energy. It is used in various applications, from cooking and space heating to an extremely wide range of industrial applications. While at domestic levels it is used at lower temperatures, industrial use requires much higher temperatures. Storage and transfer is an important consideration in the usage of heat. Steam has been widely used over the years as a medium of heat transfer mainly due to the advantage of its high latent heat content. It is interesting to note that steam is just another form of water, an entity most familiar to the mankind next to air (to be specific, oxygen). In industry, steam is used as an economical and easy mode of heating for various applications like – (1) Unit Operations in Chemical Industry, (2) Textile industry, (3) Polymer and paint industry, etc.

For a developed country like US, industrial sector consumes about 40% of country's commercial energy. Of the total energy used by industry, a major portion, (approximately 45–65%) is used for direct thermal applications in the preparation and treatment of goods, as listed above, and is known as Industrial Process Heat (IPH). The thermal energy for IPH, in general is below the temperature of 300 °C. the percentage of IPH demand utilized in the temperature range of 92–204 °C is 37.2% of the total IPH. The largest share of the total IPH demand is currently met by steam (Thomas, 1995).

1.1. A case of developing country like India

Considering India's energy consumption pattern, industrial share is at 27.1% (Earth Trends, 2003). India's primary energy demand in 2005 was 537 Mtoe (Million

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Performance analysis of a novel and cost effective CPC system

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ABSTRACT

Compound Parabolic Collectors (CPCs) allow large acceptance angle which concentrating the incident radiation and need only occasional tilt adjustments instead of continuous solar tracking. They have, therefore, been found useful in many low concentration applications, where ease of operation, and low cost are important criteria. In addition, researchers have recently shown that in conjunction with other concentrators, CPC can do value addition to Fresnel or heliostat technologies. Also, their usefulness in solar reactors for water disinfection or hydrogen production has been reported. One major limitation of CPC is its height which increases rapidly with an increase in the aperture, rendering the supporting structure bulky and costly. Truncation reduces height, however also reduces the concentration. An improvement in the CPC design has been suggested in this paper, which brings down its height, without much compromise on the concentration ratio. A prototype of this modified CPC design was constructed and tested for thermal efficiencies and achievable temperatures. Results show that the modified CPC design can harness the solar energy to provide low cost Industrial Process Heat.

1. Introduction

In commercial solar thermal installations, the Parabolic Trough Collectors (PTCs) are used frequently. However, some other designs are also considered, because of their specific advantages. For instance, a Compound Parabolic Collector (CPC) is capable of concentrating sunlight onto a flat receiver over a full day, without tracking. Unlike other solar concentrators, therefore, CPC does not require elaborate tracking arrangement; and thus provides the advantage of ease of operation. Consequently, during the past 30 years attempts have been made to understand the characteristic features of CPC, and to develop its several applications.

1.1. Compound Parabolic Collectors (CPCs)

Concept of CPC was introduced by Winston [1] in 1974, which is a non-imaging type of concentrator. As seen from Fig. 1, CPC consists of sections of two parabolas 'A' and 'B', with their focal points at 'F_A' and 'F_B' respectively, such that the former lies on curve 'B'; and the later lies on the curve 'A'. The dotted portions of the two curves are truncated; and only the parts shown by solid lines constitute the CPC. Angle between the two lines drawn parallel to the axes of parabolas 'A' and 'B' through 'F_B' and 'F_A' respectively is its angle of acceptance '2θ'. Rays entering CPC through '2θ' reach the gap between 'F_A' and 'F_B', after a single or multiple reflections, producing a non-imaging type of concentration. The geometrical concentration of the CPC is ($d1/d2$) where $d1$ is aperture and $d2$ is receiver opening (Which is shown as (10) and (11) in Fig. 1). It is also clear from the figure that sections of both the parabolas, forming a CPC are above their respective focal planes.

Muschaweck et al. [2] showed that except near the equator, asymmetric CPC collectors collect more solar energy than the symmetric ones by advantageous land-use; and with marginally higher construction cost. Mills et al. [3] have pointed out recommended that the East–West alignment the absorbers of CPC collectors offer for higher annual output as compared to the North–South alignment.

In operation, CPC is deployed with its linear receiver aligned East–West, and aperture typically tilted toward south (for locations in the northern hemisphere). The tilt is such that the incident solar rays enter the collector within its acceptance angle; and it is adjusted periodically when the incident rays just spill out beyond that angle. Also, CPC is often truncated at the top in practice to restrict its height; but at the cost of drop in its concentration ratio.

1.2. Applications of CPC

The concentration ratio of CPC is known to have relatively low values, as compared to parabolic dish or trough concentrators, and generate lower temperatures. Researchers have worked on many thermal applications of CPC, where ease of operation is

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A Novel Method to Improve the Efficiency of a Cooking Device Via Thermal Insulation

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We propose a method of finding the transient temperature variation in an insulated cooking device. We also report a means of optimising the thickness of insulation. The cooking device is a double walled cylindrical vessel with spacing of 5–20 mm between the vertical walls (width) and spacing of 560 or 870 mm between top and bottom surfaces (height). The height to width ratio (H/L) is between 28 and 174 and Rayleigh number (Ra) is between 907 and 2.61×10^5. First, an energy balance for the cooking device is established. A correlation is developed to predict the heat transfer coefficient (HTC) as a function of Ra and H/L. The method developed for finding the transient variation in temperature has been tested on two cooking device volumes: 120 and 700 lit Using the optimised parameters, a reduction in heat loss of 22% and 30%, respectively, is observed.

Keywords: heat transfer, computational fluid dynamics, vertical slots, insulation, cooking device

INTRODUCTION

Minimising thermal energy loss using an air gap as insulation has been of interest to researchers over several decades. Theoretical (Batchelor, 1954; Elder, 1965), experimental (Yin et al., 1978; Elsherbiny et al., 1982; Wakitani, 1994) and numerical approaches have been used to investigate the heat transfer phenomena in such an insulating gap; involving several geometries and configurations (Newell and Schmidt, 1970; Korpela et al., 1982; Lee and Korpela, 1983; Le Quéré, 1990; Mohamad, 1995; Wakitani, 1996, 1997; Zhao et al., 1997; Lartigue et al., 2000; Ganguli et al., 2009; Mohamad et al., 2009). A detailed review of some of the most important studies has been presented by Ganguli et al. (2009). It is generally accepted that the ratio of the lateral to transverse dimensions of the gap (Aspect Ratio, AR or H:L ratio) and the Rayleigh number (Ra) in the gap are the most important parameters determining the performance.

In developing countries, out of the total energy consumption, about 30% (Legros et al., 2009) is used for cooking. The conventional open pan cooking method has an efficiency of about 15–20%, while the pressure based cooking devices have net thermal efficiencies in the range of 35–40%. The heat source for cooking is the burning of fuels like charcoal, kerosene, wood, liquefied petroleum gas (LPG), compressed natural gas (CNG), etc. A preliminary analysis of conventional (unpressurised) cooking methods shows that the major sources of thermal inefficiency are (a) non-optimal fuel burning rates, (b) use of excess water (especially in the case of rice cooking) and (c) practically unrestricted heat losses to the surroundings. Pressure based cooking devices, while more efficient, are limited by safety concerns restricted to a maximum of 30 lit capacities (though most common units have a capacity range of 7–10 lit).

A special type of cooking device called Eco-cooker (www.ecocooker.org) serves to provide energy efficient cooking (thermal efficiency of up to 72%) at larger capacities. Unlike pressure based cooking devices, it works at atmospheric pressure, is configured to burn fuel at an optimised rate and to minimise heat losses. This cooking device can cook food on various scales of operation ranging from 4.5 and 6 lit for domestic scale cooking to 700 lit for community and commercial cooking. The Eco-cooker is essentially a cooking device (double walled cylindrical vessel with a single walled flame-heated bottom). The distance between the burner and the bottom of the cooking device is optimised so that the flame region is centred and is

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Development of Efficient Designs of Cooking Systems. III. Kinetics of Cooking and Quality of Cooked Food, Including Nutrients, Anti-Nutrients, Taste, and Flavor

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ABSTRACT: Part III of the series on cooking systems presents a qualitative description of cooking methods such as open pan cooking, pressure cooking, steam cooking, solar energy-based cooking, microwave cooking, etc. A large number of chemical and physical changes occur during the process of cooking. These changes have been comprehensively covered in published literature including some textbooks. An attempt has been made to discuss a brief coherent description regarding the changes occurring in starches, proteins, fats, etc. The kinetics of the cooking reaction has also been investigated. This information can be advantageously employed for developing a protocol for an optimum temperature−time program. Because the cooking process is practically thermally neutral, a good scope is available for the optimization of energy supply. It was also thought desirable to understand the kinetics of degradation of proteins, vitamins, anti-nutrients, and flavors in different cooking practices, including microwave ovens and pressure cookers. The mechanism of cooking of rice and lentils has been described. The cooking process involves first the transfer of water from bulk to the particle surface, where the resistance for transfer is provided by a thin film in the vicinity of grain (rice and lentils) surfaces. Second, water has to transfer from the external surface to swollen cooked mass to uncooked core. Finally, on the surface of the uncooked core, the cooking reaction occurs. All published literature regarding this mechanism has been systematically analyzed, and the procedure has been given regarding the rate controlling step(s) and the estimation of the overall rate of cooking. For this purpose, the mathematical models have been given and methods have been described for the quantitative evaluation of the model parameters. A substantial amount of additional work is needed on the mechanism of cooking and suggestions have been made for future research.

1. INTRODUCTION

Part I[1] of the series on cooking systems was related to the development of cooker design. Part II[2] consisted of the design optimization of the cooker geometry using computational fluid dynamics (Section 2) and experiments on cooking of rice and lentils (Section 3). It also dealt with optimum selection of gas burners and first level selection of renewable energy sources. Thus, after considering the various aspects of the cooker design in Parts I and II, it was thought desirable to analyze the actual cooking process. Accordingly, Section 2 of this paper briefly overviews the various cooking practices that are commonly employed. Section 3 of this paper describes the phyisco−chemical changes occurring during cooking of some major constituents such as carbohydrates, proteins, and fats and also some minor constituents such as vitamins, minerals, anti-nutrients, pigments, etc.

Section 4 of this paper is concerned with quality of cooked food including nutrients, anti-nutrients, taste, and flavor. The kinetics of change during the cooking process of these constituents has been reported in the published literature. Here, we have carefully analyzed the published information and presented it in a coherent theme.

Finally, Section 5 deals with the kinetic description of change occurring at the particle level of rice and lentils. The classical chemical engineering approach has been adopted for the determination of the rate controlling step(s) during the cooking process that includes external mass transfer, diffusion through the swollen cooked layer, and finally, the physico−chemical changes occurring on the surface of the uncooked core. All of the published literature has been analyzed, and recommendation have been made for future work.

2. COOKING PRACTICES

Various heating methods ranging from three stone fires to electrical, microwave, and induction ovens have been used over the years for cooking. Depending on the method used, the efficiency of operation may vary from 10% to 15% for conventional cooking to levels up to 80% for thermally efficient cooking devices.

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