International Journal of Energy Optimization and Engineering
Volume 9 • Issue 2 • April-June 2020

Research Methodology for Microwave-Convective Processing of Grain

Aleksey N. Vasiliev, Federal State Budgetary Scientific Institution "Federal Scientific Agroengineering Center VIM", Moscow, Russian Federation

https://orcid.org/0000-0002-7988-2338

V.P. Goryachkina, Federal State Budgetary Scientific Institution "Federal Scientific Agroengineering Center VIM", Moscow, Russian Federation

Dmitry Budnikov, Federal State Budgetary Scientific Institution "Federal Scientific Agroengineering Center VIM", Moscow, Russian Federation

https://orcid.org/0000-0002-8729-1300

ABSTRACT

Studying the effect of microwave fields on the intensification of heat and moisture exchange processes in a granular layer is a rather complicated task, which cannot be effectively solved without an adequate research methodology. In presented materials, a system of principles and approaches for studying processes of microwave-convective grain treatment has been discussed. Based on the explicitly defined process target, functional-physical analysis has been performed that made it possible to specify the most essential factors of process. Morphological analysis of processes shall be performed in several stages. At each stage, targets of process have to be set by excluding combinations of factors that have no reason to be considered at this particular stage of process development. Application of mathematical simulation methods is advisable for selection of optimal options.

KEYWORDS

Air Velocity, Functional-Physical Analysis, Grain, Grain Temperature, Methodology, Microwave Field, Microwave-Convective Treatment, Moisture Content of Grain, Morphological Analysis

INTRODUCTION

In technological processes of grain post-harvest handling, those involving thermal treatment belong to leaders, in terms of energy consumption. However, it is impossible to avoid these processes since they are commonly applied in grain drying and sanitation techniques. That is why reduction of energy intensity of these processes is a problem of prime importance.

Application of microwave electromagnetic fields is regarded as one of the effective methods for energy consumption reduction in grain drying and sanitation technologies, in which case grain dielectric properties are employed for its heating. It makes it possible to avoid energy loss associated with heat consumed by heat-carrier and removed from a technological cycle. In case of grain convective drying, gradients of temperature and moisture content are oppositely directional, within grain seeds,

DOI: 10.4018/IJEOE.2020040101

which adversely affects process effectiveness. When microwave heating is used internal layers of seeds are heated to higher temperatures owing to their higher moisture content. Therefore, gradients of moisture content and temperature are unidirectional. That is why energy consumption for grain drying is lower compared to conventional convective drying techniques (Ospanov, Vasilyev et al., 2017; Budnikov & Vasiliev, 2018).

Studies in the field of microwave technologies application in grain postharvest handling, particularly for grain drying, have been carried out for many years (Horynski, 1999; Kupfer, 1999; Barbosa-Canovas, Vega-Mercado, & Gongora-Nieto, 2001; Jumah & Raghavan, 2001). Nevertheless, implementation of these technologies in agricultural production has not yet gained desirable scales. It can be explained by the need to employ more complicated equipment compared to conventional convective drying methods. But, in a greater degree, it is associated with the absence of required nomenclature of reliable equipment and machinery. However, such machinery cannot be designed without detailed and comprehensive study of convective heat-and-moisture exchange processes in grain layer under the effect of microwave fields. For this purpose, an adequate research methodology has to be developed.

RESEARCH METHOD

Methodology, in its practical sense, is a system of principles and approaches for research activities that have to be adhered by researchers in the course of obtaining and development of knowledge, in the frames of a specified problem (Novikov & Novikov, 2013; Lukashevich, 2001, Ruzavin, 1975). The following system of principles and operation sequence was applied in the course of studying the process of microwave-convective treatment of grain:

1. Development of process block diagram;
2. Development of the target statement for technological process;
3. Defining controlled parameters, control actions, initial conditions and status options for the object under control;
4. Application of functional-physical analysis to controlled parameters, control actions, initial conditions and status options of the controlled object;
5. Morphological analysis of the process under development and selection of appropriate variants of initial conditions, controlled parameters and control actions. Adjusting the purpose of the process;
6. Development of mathematical model for the process under study:
    a. Description of dynamic properties of the subject of research;
    b. Specifying initial and boundary conditions;
7. Method selection for mathematical model solution. Solving the problem;
8. Software selection for dynamic programming of the process under development;
9. Implementation of mathematical model with the use of computer. Program checkout. Model-based analysis of the process under study;
10. Optimization procedure. Application of computer simulation technique for optimization of parameters of the process under study or for that of design parameters of equipment used to implement this process;
11. Planning of experimental studies designed to check validity of model-based analysis results;
12. Development of experimental equipment and carrying out experimental studies;
13. Experimental results analysis;
14. Adjustment of the mathematical model of the process.

In accordance with the described sequence, it is advisable, at the first stage, to design block diagram for technological process under study. For the process of microwave-convective grain treatment, this diagram has the following layout (see Figure 1).