

## REVIEW OF JOURNALS WITH A PARTICULAR EMPHASIS ON PAPERS ON APPLICATION OF INVERSE APPROACH IN DRYING PROCESSES

### PREGLED ČASOPISA SA POSEBNIM NAGLASKOM NA RADOVE O PRIMENI INVERZNOG PRISTUPA U PROCESIMA SUŠENJA

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#### ABSTRACT

The main idea of this paper is to review and present the scientific papers in which inverse approach was used. For this purpose, the number of publications, references, etc., in ten relevant journals (*Journal of Food Engineering, International Journal of Heat and Mass Transfer, Inverse Problems in Science and Engineering, International Journal of Food Properties, Computers & Mathematics with Applications, International Journal of Thermal Sciences, Drying Technology: An International Journal, International Journal of Food Science & Technology, Journal of Engineering Physics and Thermophysics, LWT - Food Science and Technology*) were studied. In order to obtain clear picture of what is realistic to expect from the scientific investigation in this field in the near future and where future research should be focused, some statistical analysis were made. From the performed statistical analysis it was concluded that more investigations are needed for determination of the thermophysical and engineering characteristics of food materials.

**Key words:** review, survey, journals, inverse approach.

#### REZIME

Glavna ideja ovog rada je pregled i prikazivanje naučnih radova u kojima je primenjen inverzni pristup. U tu svrhu, istraživane su brojne publikacije i reference u deset relevantnih žurnala (*Journal of Food Engineering, International Journal of Heat and Mass Transfer, Inverse Problems in Science and Engineering, International Journal of Food Properties, Computers & Mathematics with Applications, International Journal of Thermal Sciences, Drying Technology: An International Journal, International Journal of Food Science & Technology, Journal of Engineering Physics and Thermophysics, LWT – Food Science and Technology*). Da bi se dobila jasna slika o tome šta se može realno očekivati iz naučnih istraživanja u ovom području u skorij budućnosti i gde bi se buduća istraživanja trebala fokusirati, urađene su statističke analize. Iz izvršenih statističkih analiza može se zaključiti da su potrebna veća i sveobuhvatna istraživanja za određivanje termofizičkih i inženjerskih karakteristika prehrambenih materijala.

**Ključne reči:** pregled, žurnali, inverzni pristup.

#### INTRODUCTION

Inverse approach to parameter estimation in last few decades has become widely used in various scientific disciplines. Application of inverse approaches to estimation of thermophysical properties of food materials and heat and mass coefficients is very popular in last years (Kanevce et al., 2002; 2006; 2006a; 2007; 2007a; 2008; Mitrevski et al., 2006; 2009). In order to find out papers (i.e. so-called reference papers) in which inverse approach for determination of unknown parameters were applied, surveys in ten relevant journals were made:

- Journal of Food Engineering-JFE
- International Journal of Heat and Mass Transfer-IJHMT
- Inverse Problems in Science and Engineering-IPSE
- International Journal of Food Properties-IJFP
- Computers & Mathematics with Applications-CMA
- International Journal of Thermal Sciences-IJTS
- Drying Technology: An International Journal-DTIJ
- International Journal of Food Science&Technology-IJFST
- Journal of Engineering Physics and Thermophysics-JEPT
- LWT-Food Science and Technology-LWT FST.

The research conducted within the papers published in these journals should give an answer to the following questions:

- Which trends can be deduced from the advances in published papers and references publications in recent years?

- What is realistic to expect from the scientific investigation in this fields in the near future and where future research in this field should be focused?
- What kind of inverse problems have been used in reference papers?

#### Some historical data

Easy access to electronic database on editions of each journal makes it possible nowadays to find data on history of papers in which inverse approach was applied. Each journal has begun with electronic issue from a different year. The electronic issue from 1966 in the International Journal of Food Science and Technology is the oldest, while the issue from 1998 for the International Journal of Food Properties is with the latest date. The surveys in each journal were made for period when journal started with own edition, until the first half of 2013. On Figure 1, the results of the surveys in ten relevant journals are shown.

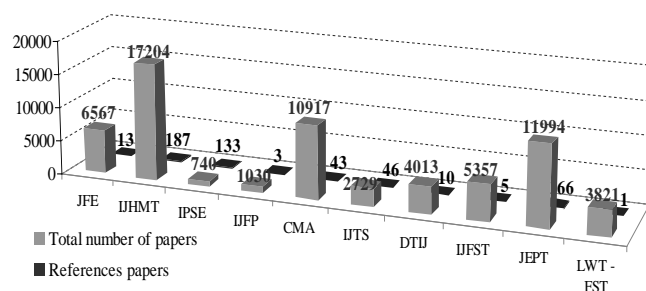


Fig. 1. Publications in ten relevant journals

It may be noted that the number of papers in which inverse method was applied is quite different and low in comparison with the total number of published papers. Exception is the journal *Inverse Problems in Science and Engineering* which hosts 133 reference papers i.e. 17.97% out of total number of published papers - 740. Others journal host from 1.69% of reference papers (*International Journal of Thermal Sciences*), while the least part - 0.03% reference papers in the journal *LWT-Food Science and Technology*. The reasons are probably of different nature. It depends on the character of the journals, topics, aim, scope, year when edition started, etc. Besides the application of inverse problems, papers published in these journals deal with others topics like introduction of new technologies, examinations, new methods of measuring, comparison to others technologies, etc.

From Figure 2 to Figure 12 chronologically are shown the total numbers of published papers and reference papers for each journal separately. Out of the total number of published papers (6567) in *Journal of Food Engineering*, only 13 papers i.e. 0.2% refer to application of the inverse approach. From Figure 2, it can be noticed that from 1982 to 2003 there is no any reference paper. First reference paper was published in 2004, but from 2005 to 2013 the number of reference papers is also insignificant.

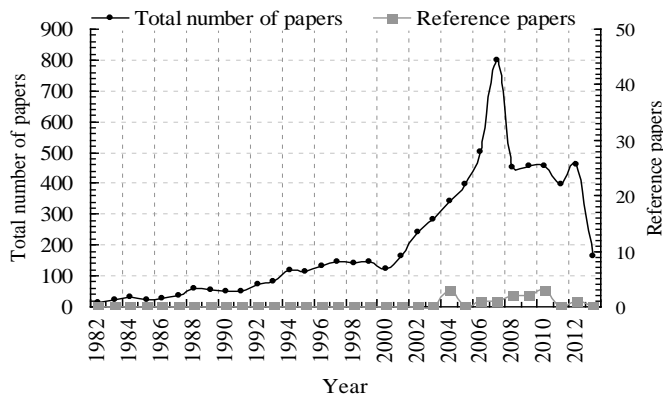


Fig. 2. Evolution of papers and reference papers published in the *Journal of Food Engineering*

*Journal of Heat and Mass Transfer* is focused on analytical and experimental research, with an emphasis on contributions which increase the basic understanding of transfer processes and their application to engineering problems. From 1960 up to 2013, 17204 papers were published in this journal, out of which 187 papers, i.e. 1.09% are reference papers. From Figure 3 it is obvious that insignificant number of reference papers were published from 1960 to 1994.

Then, from 1995 to 2013 there is an increase in number of publications, excluding 2005 when only 2 papers were published.

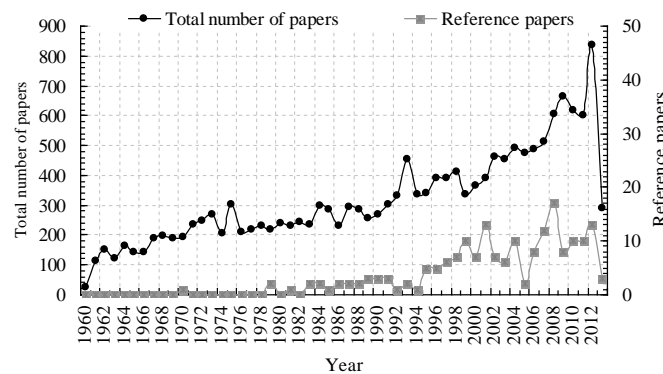


Fig. 3. Evolution of papers and reference papers published in *International Journal of Heat and Mass Transfer*

*Journal Inverse Problems in Science and Engineering* hosts the highest number of reference papers, 133, while the total number of published papers is 740. From 1995 until 2013 there is a stable trend with picks in years 2004 and 2008 (Figure 4).

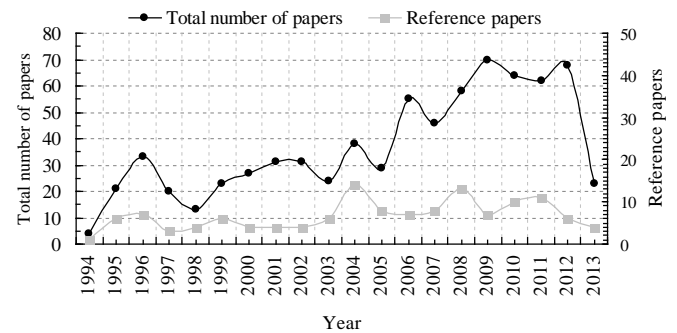


Fig. 4. Evolution of papers and reference papers published in *Inverse Problems in Science and Engineering*

In the *International Journal of Food Properties* from 1998 to 2013, total of 1030 papers were published but only 3 of them i.e. 0.29% refer to applied inverse approach (Figure 5).

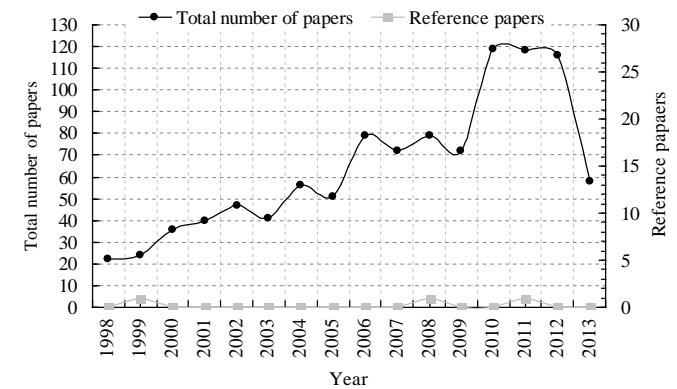


Fig. 5. Evolution of papers and reference papers published in *International Journal of Food Properties*

Out of the total number of published papers (10917) in *Journal Computers&Mathematics with Applications*, 43 papers i.e. 0.39% are referent. From Figure 6 it can be noticed that from 1975 to 1987 there is no any reference paper. First reference paper was published in 1988 and in onwards editions, insignificant number of papers were published (maximum of 4 papers were published in years 1996 and 2010).

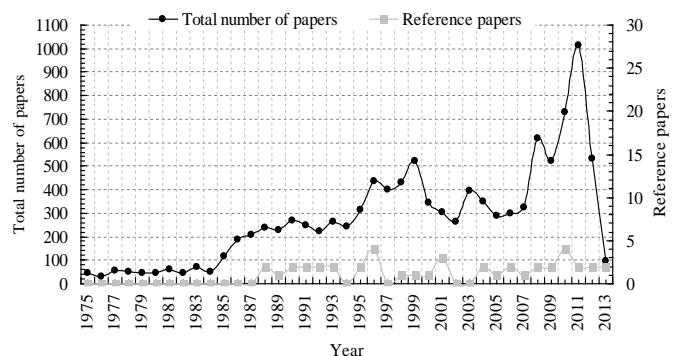


Fig. 6. Evolution of papers and reference papers published in *Computers & Mathematics with Applications*

*International Journal of Thermal Science* has electronic edition from 1996 and since then the total number of published papers is 2729, out of which 46 papers, i.e. 1.69% are reference papers. From Figure 7 it can be observed that small number of reference papers were published during entire edited period

(maximum of 7 papers were published in years 2010 and 2012 respectively).

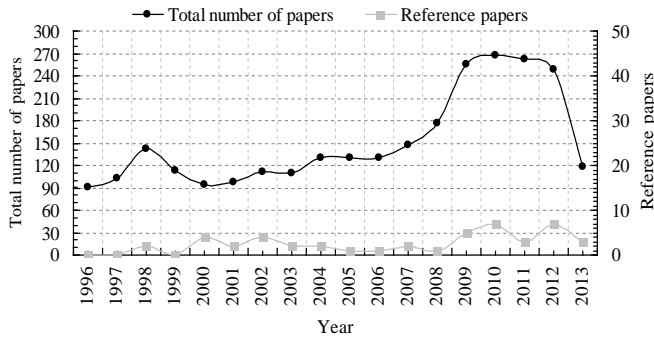


Fig. 7. Evolution of papers and reference papers published in International Journal of Thermal Science

In Drying Technology: An International Journal, from 1983 to 2013 only 10 papers i.e. 0.25% are reference, while the total number of published papers is 4013 (Figure 8).

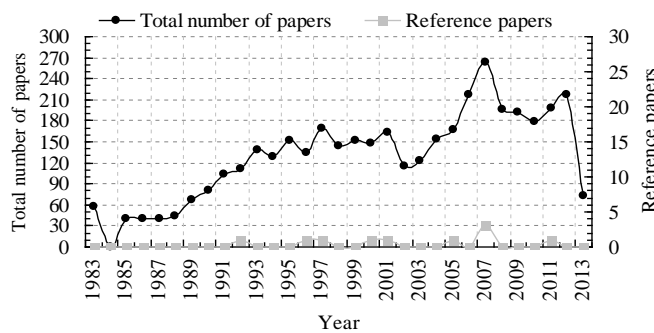


Fig. 8. Evolution of papers and reference papers published in Drying Technology: An International Journal

From 1966 until 2013 only 5 reference papers i.e. 0.09% were published in International Journal of Food Science & Technology, while the total number of published papers is 5357. Figure 9 presents the weak trend of reference papers over years.

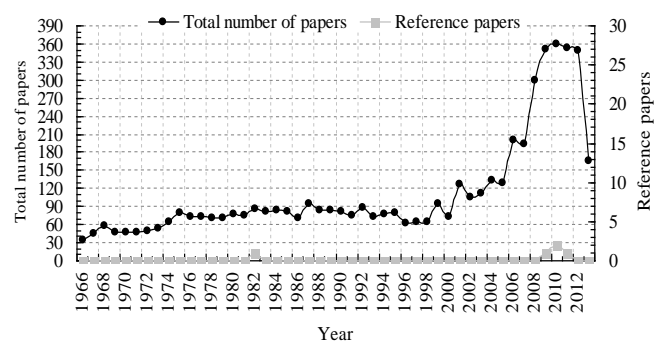


Fig. 9. Evolution of papers and inverse method papers in International Journal of Food Science & Technology

The Journal of Engineering Physics and Thermophysics is a translation of the peer-reviewed Russian language journal *Inzhenerno-fizicheskii Zhurnal*, a publication of the Academy of Sciences of Belarus. Out of the total number of published papers (11994), only 166 papers, i.e. 1.38%, are referent. From Figure 10, small number of references papers published during the edited period can be noticed. Sporadic increase can be noticed in years 1975, 1977, 1983, 1985, 1987 and 1989 when 12, 11, 20, 16, 14 and 18 papers were published, respectively.

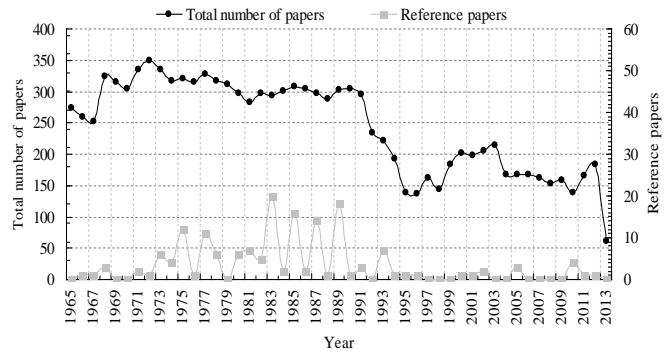


Fig. 10. Evolution of papers and reference papers published in Journal of Engineering Physics and Thermophysics

There is only one referent paper i.e. 0.03% among all published papers (3821) in LWT-Food Science and Technology (Figure 11).

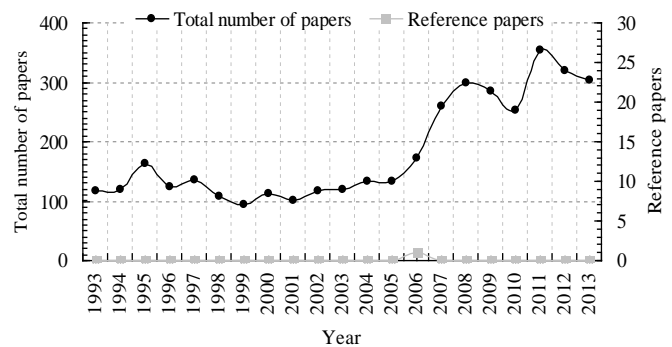


Fig. 11. Evolution of papers and reference papers published in LW-Food Science and Technology

It can be said that from 1960 to 1973 the number of reference papers is very small and till 1983 reaches insignificant number with only three peaks in years 1975, 1977 and 1983 when 12, 11 and 22 papers were published. From 1984 until now, constant increase with sporadic peaks in 1985, 1987, 1989 2001, 2004, 2008 and 2010 is obvious, when 17, 16, 22, 24, 31, 36 and 40 papers were published, (Figure 12). Researches were undertaken until the first half of 2013, so year 2013 is pending.

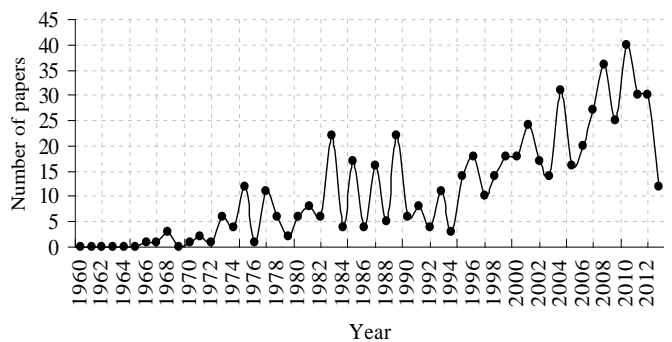


Fig. 12. Evolution of total number of reference papers

It should be concluded that three journals host over 80% of all references papers, (Journal of Heat and Mass Transfer, Inverse Problems in Science and Engineering and Journal of Engineering Physics). Others journals are less 'friendly' to accept the papers in which inverse approach was used.

### Some statistical information

In order to obtain clear picture what is realistic to expect from the scientific investigation in the field of application of inverse problems in the near future and where future research in this field should be focused, some statistical information is

required. For this reason, the papers were divided in two main groups. In the first group are papers in which were applied inverse methods in drying processes of food materials, while in the second group are papers concerning non-food materials. The papers of first group have been classified into eight categories: I. Papers in which inverse approach was applied for determination of Diffusivity; II. Thermal conductivity, III. Thermodiffusion, IV. Specific heat, V. Density, VI. Equilibrium moisture content, VII. Drying constant, VIII. Coefficients of heat and mass transfer. The papers of the second group have been classified also into eight categories: I. Papers in which inverse approach was applied for determination of Diffusivity, II. Thermal conductivity, III. Thermodiffusion, IV. Specific heat, V. Temperature, VI. Heat flux, VII. Parameters, VIII. Others.

For statistical analysis it is also interesting what kind of inverse problem is studied. For this purpose, the papers were classified in third group. The papers of this group have been classified into seven categories: I. Papers in which Inverse Heat Conduction Problem (IHCP) is applied, II. Inverse Radiation Problem (IRP), III. Inverse Convective Problem (ICP), IV. Inverse Geometry Problem (IGP), V. Inverse Diffusion Problem (IDP), VI. Inverse Heat Transfer Problem (IHTP), VII. Others.

It must be pointed out that some papers are simultaneously classified in more than one group because cover two categories.

The results of papers classification published in Journal of Food Engineering are shown on Figure 13. All 13 papers are classified in the first group and cover four categories. It is obvious that the category of papers 'Thermal conductivity' is the most frequent, 29%, while the categories 'Diffusivity', 'Thermodiffusion' and 'Specific heat' contain, 24%, 24% and 23% of papers. In this journal there are no papers from the second group, while there is not enough data to classify the papers in the third group.

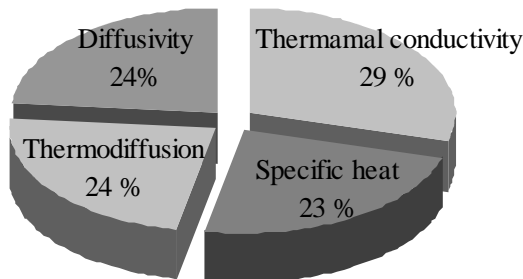


Fig. 13. Categories of the papers of first group - Journal of Food Engineering

In the Journal of Heat and Mass Transfer, published reference papers are classified in second group and the results are shown on Figure 14.

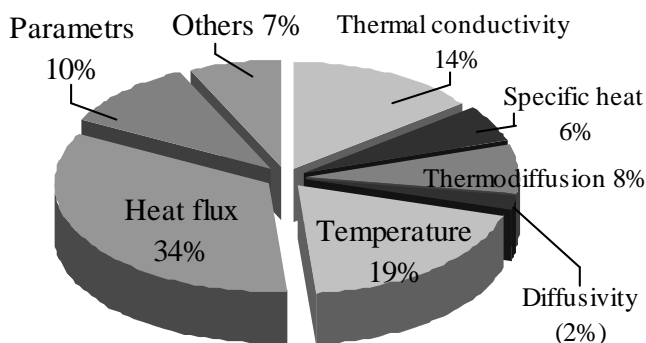


Fig. 14. Categories of the papers of second group - Journal of Heat and Mass Transfer

The most frequent category, 34%, is 'Heat flux' while 'Diffusivity' is the least frequent with 2%. In the third group, papers cover five categories and the most frequent category, 58%, is 'Inverse Heat Conduction Problem' while the others are a lot less frequent, (Figure 15).

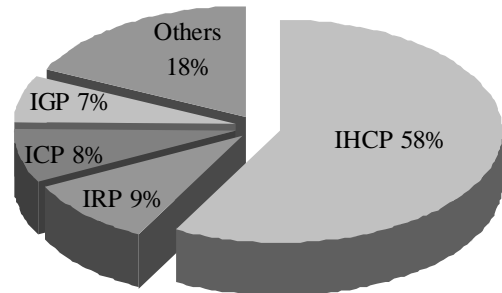


Fig. 15. Categories of the papers in third group - Journal of Heat and Mass Transfer

Reference papers published in Journal of Inverse Problems in Science and Engineering are classified in all three groups. The three papers cover three categories in the first group such as 'Thermal conductivity', 'Thermodiffusion' and 'Coefficients of heat and mass transfer'. From Figure 16 it can be seen that papers of the second group cover all eight categories. The category 'Heat flux' is the most frequent with 26% and the category 'Parameters' is the least frequent with 5%.

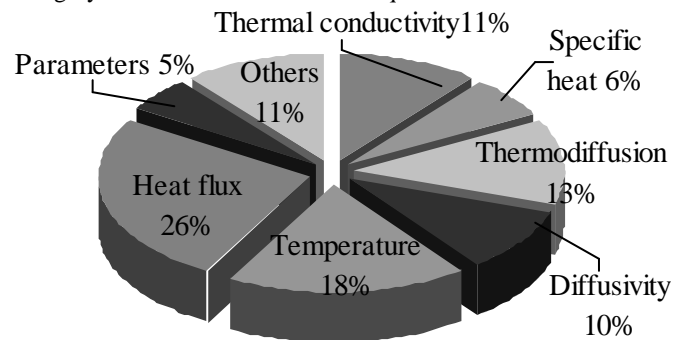


Fig. 16. Categories of the papers of second group - Inverse Problems in Science and Engineering

The papers of the third group cover five categories, where category 'Inverse Heat Conduction Problem' is the most frequent with 61% and the category 'Inverse Geometry Problem' is the least frequent with 2% (Figure 17).

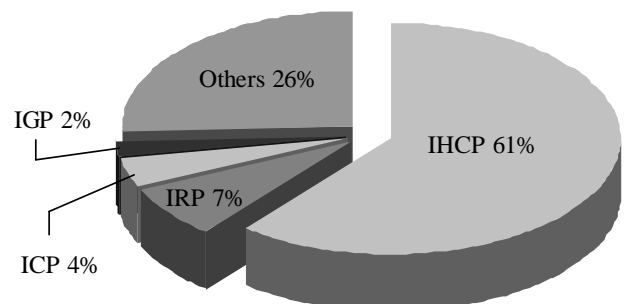


Fig. 17. Categories of the papers of third group - Inverse Problems in Science and Engineering

In International Journal of Food Properties, reference papers are classified into first and third group. Three papers of the first group covers categories: 'Thermal conductivity', 'Thermodiffusion' and 'Coefficients of heat and mass transfer'. While in the third group two papers cover category 'Inverse Heat Conduction Problem' and one paper covers category 'Others'

In the journal *Computers&Mathematics with Applications* papers covers second and third group. Figure 18 provides some statistical information for the categories of papers of second group. The most frequent, 29% is category 'Diffusivity', while the category 'Parameters' is the least frequent with 9% of the total.

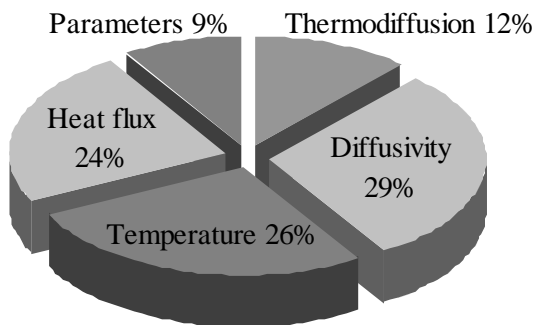


Fig. 18. Categories of the papers of second group- *Computers&Mathematics with Applications*

From Figure 19 it is obvious that the category 'Inverse Heat Conduction Problem' is the most frequent with 65% and category 'Inverse Diffusion Problem' is the least frequent with 8%.

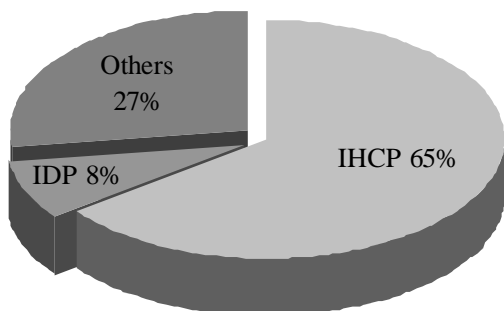


Fig. 19. Categories of the papers of third group- *Computers & Mathematics with Applications*

In *Journal of Thermal Sciences*, reference papers are classified in second and third group. From Figure 20 can be seen that all eight categories of second group are covered. The most frequent category, 28%, is 'Heat flux', while category 'Diffusivity' is the least frequent, with 4%.

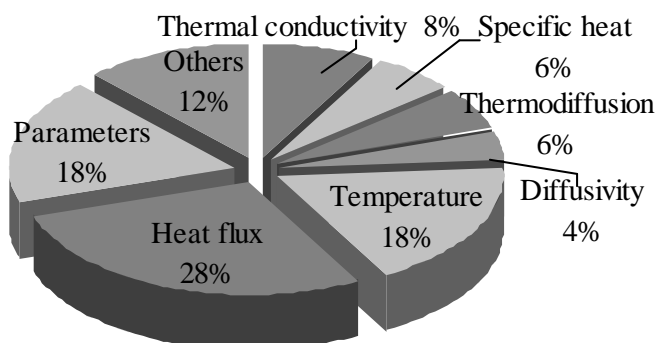


Fig. 20. Categories of the papers of second group- *Journal of Thermal Sciences*

In the third group, papers cover six categories and the most frequent category is 'Inverse Heat Conduction Problem' with 41%, while the least frequent is 'Inverse Diffusion Problem', with 6% of the total (Figure 21).

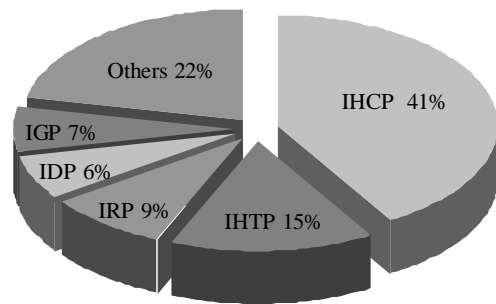


Fig. 21. Categories of the papers of third group- *Journal of Thermal Sciences*

Reference papers in *Drying Technology: An International Journal* are classified in all three groups. On Figure 22 it is obvious that papers cover three categories in first group, where the most frequent category is 'Diffusivity' with 67% and the remaining papers are less frequent. In the second group, the most frequent category is 'Diffusivity' with 67% followed by 'Coefficients' and 'Thermal conductivity' with 17% and 16%. While the category 'Inverse Diffusion Problem' is the most frequent in third group with 70%, and the category 'Inverse Heat Transfer Problem' is the least frequent with 30%.

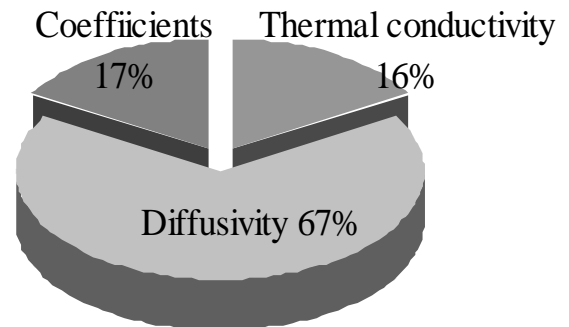


Fig. 22. Categories of the papers of first group- *Drying Technology: An International Journal*

On Figure 23, the categories of papers in first group published in *International Journal of Food Science&Technology* are shown. Two papers cover each of categories 'Diffusivity' and 'Thermodiffusion' while one paper covers category 'Thermal conductivity'.

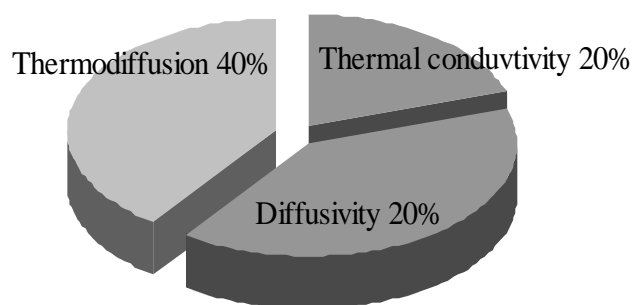


Fig. 23. Categories of the papers of first group- *International Journal of Food Science & Technology*

In the third group, three papers cover category 'Inverse Heat Transfer Problem' and two papers cover category 'Inverse Diffusion Problem' (Figure 24).

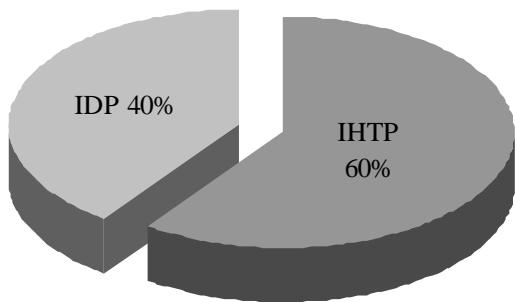


Fig. 24. Categories of the papers of third group-International Journal of Food Science & Technology

In the Journal of Engineering Physics and Thermophysics, reference papers are classified mostly in the second, non-food materials group, and in the third group.

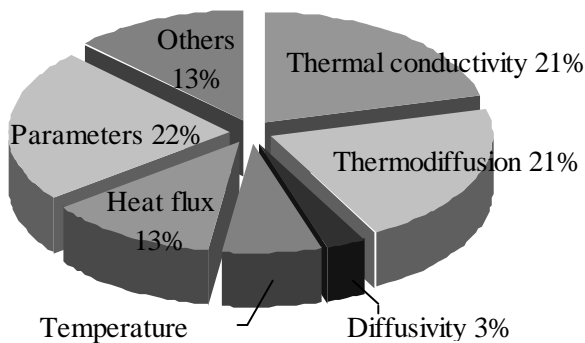


Fig. 25. Categories of the papers of second group-Journal of Engineering Physics and Thermophysics

Only one paper deals with food materials and can be classified in first group, but due to insufficient information it can not host any category. From Figure 25 it can be seen that seven categories of second group are covered. The most frequent category with 22%, is 'Parameters' while the category 'Diffusivity' is the least frequent with 3%.

In the third group, papers cover five categories and the most frequent category (70%) is 'Inverse Heat Conduction Problem' and the least frequent is 'Inverse Radiation Problem', with 2%, (Figure 26).

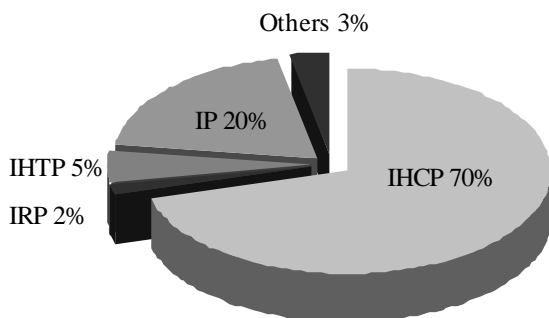


Fig. 26. Categories of the papers of third group-Journal of Engineering Physics and Thermophysics

In LWT-Food Science and Technology only one paper was published and it is classified in the first and third group. This paper covers category 'Thermodiffusion' and category 'Inverse Heat Transfer Problem'.

Statistically speaking, Figure 27 provides quantity review into development of reference papers of first group in general. The total number of papers in which application of inverse approach in drying processes was considered is 32.

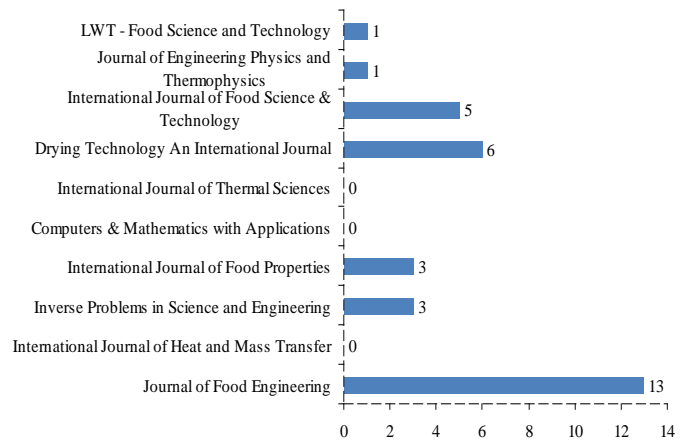


Fig. 27. Review of published papers of first group

On Figure 28 number of papers which were classified in first group-food materials, summary of all ten journals, are presented. It can be seen that the category of papers 'Diffusivity' is the most frequent with 10 papers i.e. 28.57%, while the category of papers 'Thermodiffusion' and 'Thermal conductivity' with 9 papers i.e. 25.71% each, is significant in the total number of reference papers.

The category of papers 'Specific heat' with 4 papers i.e. 11.43% and the category 'Coefficient of heat and mass transfer' with 3 papers i.e. 8.57% is still very low. The categories of papers 'Drying constant', 'Density' and 'Equilibrium moisture content' cover zero papers.

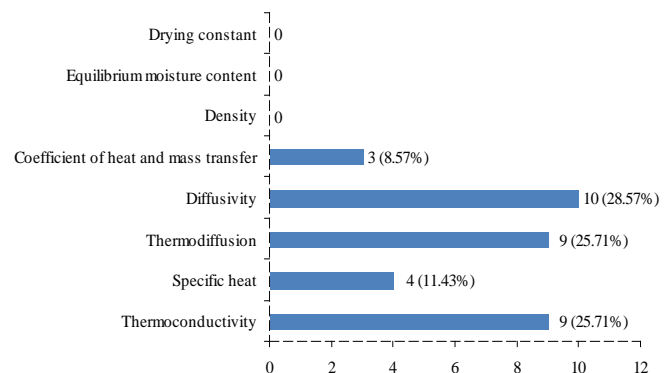


Fig. 28. Number of papers classified by categories in the first group for the ten relevant journals

From performed statistical analysis, it can be concluded that in near future scientific investigation in the field of determination in categories 'Diffusivity', 'Thermodiffusion' and 'Thermal conductivity' still remains the most attractive for food materials. But, the determination of 'Specific heat' and 'Coefficients of heat and mass transfer' does not represent less attractive field of research in near future. The categories 'Drying constant', 'Density' and 'Equilibrium moisture content' are not attractive for researchers, but, future research should be focused on determination of these engineering characteristics of food materials.

From the performed statistical analysis for second group of papers it can be said that the category 'Heat flux' covers the most reference papers, 105 i.e. 27.49% of the total, and still the categories 'Thermal conductivity', (13.35%), 'Thermodiffusion' (11.78%), 'Temperature' (13.09%) and 'Parameters' (12.83%) keep up with the previous category. The others categories: 'Specific heat' (4.45%), 'Diffusivity' (7.85%) and 'Others' (9.16%) are not negligible and more investigations are required for them.

Concerning the categories of the third group, the most dominant category 'IHCP' covers 408 papers i.e. 60.36%. The category 'Others' follows with 22.19%. The others categories: 'IRP', 'ICP', 'IGP', 'IDP', 'IHTP' with 5.18%, 2.96%, 2.81%, 3.25%, and 3.25% contain insignificant number of papers compared to the previous two categories.

## CONCLUSION

Considering the fact that the inverse approach is a relatively new method, the general impression is that papers in which were applied inverse approach participated in a small number of all journals and here are briefly enumerated the most outstanding conclusions of this paper:

- Inverse method is a kind of technique that is used for determination of various thermophysical properties, coefficients of heat and mass transfer, temperature, heat flux, etc. which is very important to estimate and predict heat and mass transfer process.
- Papers in which inverse approach is used are published in a wide variety of journals.
- Different kinds of inverse problems are used in journals, but still, Inverse Heat Conduction Problem is the most used.
- Different coefficients and parameters are determined by using various methodologies in inverse approach.
- Three Journals host over 80% of all references papers, (Journal of Heat and Mass Transfer, Inverse Problems in Science and Engineering and Journal of Engineering Physics and Thermophysics).

With reference to papers of the first category, it could be underlined that:

- Some categories traditionally are more attractive from the others, thus, there is a different level of interest in the study.
- Although categories of papers 'Diffusivity', 'Thermodiffusion' and 'Thermal conductivity' are 80% of the applications, there is still a space for determination of application of inverse approach in these categories.
- More investigations are needed for categories 'Specific heat', 'Coefficients of heat and mass transfer', 'Drying constant', 'Density' and 'Equilibrium moisture content'.

According to the performed analysis for second and third groups, the following can be concluded:

- Category 'Heat flux' is the most frequent category, followed by the categories 'Thermal conductivity', 'Thermodiffusion', 'Temperature' and 'Parameters', and for categories 'Specific

heat', 'Diffusivity' and 'Others' more investigations are required.

- Category 'IHCP' is the most useful and with the highest percentage in the third group and the remaining categories are with insignificant number of papers.

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