ADC2011

The 7th Asia-Pacific Drying Conference (ADC2011)

Abstract Proceedings

Organized by

Tianjin University of Science & Technology

September 18-20, 2011, Tianjin, China

Proceedings of the 7th Asia- Pacific Drying Conference

FOREWORD

This is the first time that the Asia-Pacific Drying Conference is being held in mainland China. I am delighted that the 7th Asia-Pacific Drying Conference (ADC2011) has attracted so much attention and has assured success. This is in no small measure to the dedicated and hard work of the team led by the Program Chair, Dr. Li of the Tianjin University of Science and Technology (TUST). This is indeed a monumental effort and a tremendous service to the drying community, not only in Asia but indeed all over the world. It is a clear reflection of the importance of drying operations found in most industries and its importance in both the energy conservation and environmental impact.

It is a full decade since the first ADC was held in Bali, Indonesia. The idea behind its inception was to provide a platform to the rapidly developing nations of Asia to benefit from R&D carried out not only in this region but also in developed nations such as Australia, New Zealand and indeed the rest of the world. I believe that this aim of the series has been met successfully. There is now a sustainable level of drying R&D in this region. We do need to incentivize younger researchers into drying research. I believe that conference like ADC2011 and its sister conferences around the world provide an effective forum for this to happen. I might add here that a recent examination of research papers published in Drying Technology- An International Journal (Taylor & Francis, USA) shows that authors from China have been making the most contributions over the past several years. The general level of drying R&D activity in Asia certainly appears to be on the rise.

On behalf of all the participants in ADC2011, I would like to extend hearty congratulations and thank Dr. Li along with his enthusiastic team for their truly outstanding effort and exemplary leadership clearly demonstrated in hosting ADC2011. Their dedicated effort in compiling these peer-reviewed Proceedings of archival value is especially noteworthy as it will benefit not only those who will participate in this event personally but also those who are unable to do so.

Arun S. Mujumdar

Singapore

PREFACE

It is my great pleasure to present this formal collection of the Proceedings of the 7th Asia-Pacific Drying Conference (ADC2011), which is held in Tianjin, China during September 18-20, 2011. ADC2011 follows the string of successful conferences focusing on drying science, engineering and technology, which were started in 1999 thanks to the vision of Prof. A. Kamaruddin of IPB, Bogor, Indonesia and Prof. Arun S. Mujumdar, then of McGill University, Montreal, Canada. The first ADC (ADC99) was held in Bali, Indonesia; this was followed by meetings held in Penang, Malaysia; Bangkok, Thailand; Kolkata, India, Hong Kong, China and Bangkok, Thailand. This biennial series has indeed followed the model of the widely acclaimed International Drying Symposium (IDS) series.

With the initial number of submitted abstracts of around 210, close to 159 full papers plus 2 plenary lectures and 9 keynote lectures were reviewed and have finally been included in the Proceedings. What is especially remarkable is that we have succeeded in obtaining peer reviews of all papers included in the Proceedings. A select number of these papers will eventually be published in archival literature, e.g., *Drying Technology*, *International Journal of Food Engineering*, after another round of selection and peer reviews.

As the Editor of the Proceedings, it is my pleasant duty to thank all the authors and reviewers who volunteered their precious time and expertise to make ADC2011 technically a major success. As the Chair of ADC2011, I am grateful to our sponsors, including the Tianjin University of Science and Technology (TUST), along with their academic and nonacademic staff, as well as other industrial and organizational sponsors for their kind support without which this event would not have been possible. My appreciation also goes to a number of graduate students for their continuing help and hard work to organize the event. Special thanks are due to Jiangsu Fanqun Drying Equipment Co., Ltd, Shandong Tianli Drying Equipment Co., Ltd, Senttech Technology Group, Shijiazhuang Gongda Chemcial Equipment Co., Ltd, Muters's Moisture Control Services (MCS) Division, and National Engineering Research Center of Drying Technology & Equipment for their support in the form of a number of awards recognizing the service as well as scientific contributions to the field of drying in general. My appreciation is also due to the members of the International Advisory/Scientific Panel for their help in publicizing the event and in reviewing abstracts and manuscripts in short order.

Li Zhanyong

Chairman , ADC2011

ACKNOWLEDGEMENTS

The 7th Asia-Pacific Drying Conference (ADC2011) would not be possible without the kind assistance and support from a number of persons and organizations. First of all, we must express my sincerest appreciation to Prof. Arun S. Mujumdar of the National University of Singapore for his continuing support and encouragement. Prof. Mujumdar has also helped with manuscript review and gave many useful advices to ensure the success of the Conference. Our gratitude also goes to the Tianjin University of Science and Technology (TUST) for giving us full support, both monetary and in other forms, to organize the Conference. Sponsorships from various companies and organizations are also gratefully acknowledged.

Our appreciation goes to all the Plenary and Keynote speakers as well as Session Chairs for their contributions. Our thanks are also due to a number of reviewers who helped tirelessly with the abstract and manuscript review processes. This form of assistance is indeed heavily responsible for the technical success of ADC2011. The organizing tasks of the conference have been taken care of by a number of graduate students at TUST, to whom we express our sincere appreciation. In particular, we thank Mr. Wu Long for his help with the setting up and maintenance of the conference website (http://jxxy.tust.edu.cn/jixiexueyuan/center/adc2011/index.asp) as well as Ms. Li Erna for her help with the logistic control of all the abstracts and manuscripts. Thanks are also due to Xu Qing, Zhang Jin, Geng Xianru, Dong Pengfei, Xie Yunjiang, Zhang Jing, Wang Kaiwei for their tireless help with so many important tasks pertaining to the organization of the Conference.

Li Zhanyong
Wu Zhonghua

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Topic 7: Grain Drying

天津科技大学

TIANJIN UNIVERCITY OF SCIENCE & TECHNOLOGY

Invitation Letter

邀 请 函

MOHAMAD DJAENI
Department of Chemical Engineering, Faculty of Engineering, Diponegoro University
Jl Prof H. Soedharto, SH, Tembalang, Semarang
Indonesia

Dear Mr.Mohamad Djaeni,

The 7th Asia-Pacific Drying Conference (ADC2011), that will take place on September 18-20, 2011 in Tianjin, China, aims to bring together researchers, scientists, engineers and graduate students to exchange and share their experiences, new ideas and research results about all aspects of drying technologies and equipments.

Herewith, on behalf of ADC2011 Organization committee , I am pleased to invite you to attend the conference and present your paper entitled "The Effect of Zeolite on Drying Rate of Corn in Mixed-Adsorption Dryer " at the conference site. It is recommended that you can apply for a visa for the period of September 16-23,2011 so that you have sufficient time for your journey in China.

尊敬的 Mohamad Djaeni 先生：

天津科技大学将于 2011 年 9 月 18-20 日举办第七届亚太地区干燥会议（ADC2011）。本次会议旨在为亚洲和太平洋地区等各国的学术、企业界同行专家提供一个很好的干燥技术及装备研究开发的交流平台。

在此，我代表会议组织委员会诚挚地邀请您参加第七届亚太地区干燥会议并就您所提交的论文“The Effect of Zeolite on Drying Rate of Corn in Mixed-Adsorption Dryer ”进行会议现场交流。 同时，建议您申请一个充裕的签证时间以便安排您的会议行程。

Sincerely Yours

Li Zhanyong （李占勇 教授）
Conference Chairman （会议主席）
7th Asia-Pacific Drying Conference（第七届亚太地区干燥会议）

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To whom it may concern

September, 18th201

It is herewith certified that

Mohamad Djaeni
Department of Chemical Engineering
Faculty of Engineering, Diponegoro University
Jl Prof H. Soedharto, SH, Tembalang, Semarang
Indonesia

attended the

"7th Asia-Pacific Drying Conference - ADC2011"

which took place in Tianjin, China, from September 18th - 20th 2011.
The registration fee of U$400.00 is already paid.

He presented the following paper in this conference:
The Effect of Zeolite on Drying Rate of Corn in Mixed-Adsorption D
Mohamad Djaeni, Hargono Hargono and Luqman Buchori

Li Zhanyong
Conference Chairman
7th Asia-Pacific Drying Conference

THE EFFECT OF ZEOLITE ON DRYING RATE OF CORN IN MIXED-ADSORPTION DRYER

Mohamad Djaeni, Hargono Hargono and Luqman Buchori

Department of Chemical Engineering, Faculty of Engineering, Diponegoro University
Jl Prof H. Soedharto, SH, Tembalang, Semarang
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Abstract: Mixed-adsorption drying with zeolite is an option to improve driving force for drying corn. In this case, zeolite and corn are mixed and fluidized by air. The air will evaporate water from corn, whereas zeolite will adsorb water from the air. This paper discusses the effect of two types of zeolites (zeolite 3A, natural zeolite), and air temperature (30,40, 50^{o}C), on the drying rate. At all cases, the presence of zeolites can improve drying rate up to 10-20% faster than that of drying without zeolite. The increase of zeolite percentage and air temperature can enhance drying rate.

Keywords: mixed-adsorption, drying, zeolite, fluidized, fraction

INTRODUCTION

Corn (*Zea mays* L.) is one of main food resources in the world. It contains carbohydrate, protein, and edible oil (Anonymous, 2011). Post harvest treatment such as drying is an important steps to produce high quility of corn since it determines the water content and ingredients and long life storage.

Currently, there are several drying process applied for corn, in example: direct sun drying, microwave, fluidization, and vacuum freeze drying. Direct sun drying is simplest but weather dependency for dry product quality as well as process continuity (Djaeni, 2008). The conventional fluidized bed can speed up drying rate. However, it still deals with low product quality. Meanwhile, modern drying technology such as microwave and vacuum freeze dryer can improve product quality, but it still deals with energy efficiency (Djaeni, 2008; Ratti, 2001).

Mixed-adsorption drying with water adsorbent such as zeolite is an option to improve product quality as well as energy efficiency. In this case, zeolite and the seed product such as corn are mixed in a column and fluidized by air as drying medium. The air will evaporate water from the product, and at the same time, zeolite will adsorb vapor from air. As results, air humidiy can be kept low. Moreover, operational temperature can be maintained at the certain condition due to the latent heat of adsorption. Thus, the driving force of drying can be kept high.

Zeolite is an alumino-silicate compound with tetrahedral bound linked by oxygen. Atom Al is negative that can be neralized by cation. The exchangable cation affects the adsorption ability of zeolite. Beside that, the ability is also influenced by Si/Al ratio, surface area, and size od zeolite pore (Ozkan and Ulku, 2008; Ackley et al, 2003 and Gruszkiewicz et al, 2005). In Indonesia, the natural zeolite is available in market. Even, the potential of zeolite production is high (Senda et al, 2006). However, adsorbing capacity of natural zeolite is too low rounding 0.7-0.9 gr water/gr dry zeolite. By activation using KOH, the adsorbing capacity can be enhanced up to 1.5-1.7 gr water/gr zeolite.

This paper discusses the effect of the activated natural zeolite to dry corn. As comparison, the commercial Zeolite 3A obtained ed from Zeochem was also used. Both zeolite was mixed with corn at various weight percentage and temperature. Their performance in term of drying rate was observed and compared.

STATE OF THE ART

Drying Technology Development

At present, several drying methods have been used, ranging from traditional to modern processing: e.g. direct sun drying, convective drying, microwave and infra-red drying, freeze and vacuum drying. Current drying technology is often not efficient in terms of energy consumption and has a high environmental impact due to combustion of fossil fuel or wood as energy source (Kudra and Mujumdar, 2002). The sources of fossil fuel are limited, the price of energy increases, the world wide industrial energy usage rises, and increase of greenhouse gas emission becomes a global issue due to climate change; the need for a sustainable industrial development with low capital and running cost especially for energy becomes more and more important. In this context the development of efficient drying methods with low energy consumption is an important issue (Djaeni, 2008).

Considering the energy efficiency and product quality aspects, it is a challenge to work on the development of innovative dryers with a high drying rate, high energy efficiency, low investment and operational costs, and feasible for low and medium drying temperatures. Air dehumidification with adsorbents such as pillared clay, zeolite, silica, alumina, improves the driving force for drying (faster drying rate or shorter drying time), and allows drying at low and medium temperatures and atmospheric pressure (Alikhan et al., 1992; Ratti, 2001; Revilla et al., 2006).

In adsorption dryer, the water in air is removed by contacting with an adsorbent. Hence, the humidity of air will be low. Beside that, during the process, a quantity of adsorption heat will be released in which increases the sensible heat of medium for drying. By taking into account the energy for standard regeneration of adsorbents, energy savings compared to a conventional dryer are estimated to be around 10-15% (Djaeni et al., 2007). The efficiency can be improved by adding stage number both for adsorption and drying process. With three stages number operated in 40-80^{o}C, the energy efficiency can reach 85-90% (Djaeni et al.,2009).

The next questions for the adsorption dryer are which product can be dried, how the design look like, and how the dryer can give significant improvement. There are two options for adsorption dryer design namely in-direct contact (Djaeni et al., 2009) and direct contact. At in-direct contact, the adsorbent is put in separated equipment such as shift column or rotary wheel. Air as drying medium is contacted and dehumidified before used for drying (Djaeni et al., 2009). This way is suitable for drying extracted coffea, milk, pharmaceutical, and sticky material that are conducted in spray or tray dryer. The second one is direct contact adsorption dryer where adsorbent and product is mixed in dryer. Hence, two processes (drying product and air dehumidification) can occurs simultaneously. We call this method as mixed-adsorption dryer that is suitable for drying seed, granule and non-sticky material such as grains. The process can be conducted in fluidised bed or rotary dryer.

Principle of Mixed-Adsorption Dryer

In the process, air will evaporate water from the product, while the vapor in air air will be adsorbed by solid adsorbent. Fig. 1 presents mixed-adsorption dryer with zeolite.

Firstly, dry air will contact with corn. The heat is transferred to product (suppose corn), and water will be desorbed from product to air. A s a result, the air temperature will decrease and vapor content increases. Secondly, the zeolite having affinity to water, will adsorb water from air quickly. As a result much adsorption heat releases to the air. The two adventegous will be obtained: temperature of air increases, and vapor content decreases. So, the capacity air to evaporate water from product increases (can be kept high). The process occurs simultaneously and repeated several times until zeolite saturate with water.

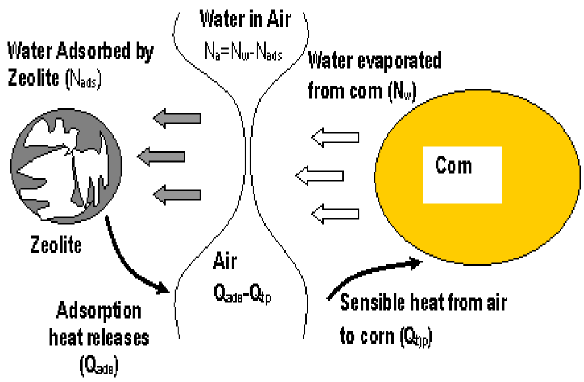

Fig. 1. Mixed-Adsorption Dryer With Zeolite

MATERIAL AND METHODS

Adsorbent Preparation

This research used two kinds of zeolites for adsorbing water from air. They arenatural zeolite mined from Klaten, Central Java, Indonesia, and Zeolite 3A provided by Zeochem, Switzerland. Firstly, the natural zeolite was activated by KOH to improve water loaded capacity. The procedure is as follows:

1) The natural zeolite was mixed with KOH 0.5N and stirred under 60-70^{o}C for 2 hours.
2) The zeolite was washed by water and dried at 110^{o}C for 4 hours. It was then cooled cooled in desicator.
3) The water loaded capacity was tested in sorption-isotherm at various temperature and relative humidity.
4) While, the surface texture was analyzed by scanning electron microscopy (SEM)

Result showed that the activated natural zeolite can adsorb water up to 0.17 gram water/gram dry zeolite under atmospheric condition. Meanwhile, SEM analysis showed the porosity of activated natural zeolite seems more uniform with bulk density 1100 kg/m^3.

However, this achievement is still lower than that of Zeolite 3A with water loaded capacity 0.22 gram water/gram zeolite (Anonymous, 2008). In addition, the pores of Zeolite 3A is uniform with size of 3^{o}A and porosity 0.4 with bulk density 740 kg/m^3 (Anonymous, 2008).

Drying Process

The research aimed to study the presence of zeolite (natural zeolite and Zeolite 3A) and operating temperature on ehancing drying rate of corn conducted in fluidized bed dryer (see Fig. 2). In this case, the both zeolites were made in granules with size of 2 mm.

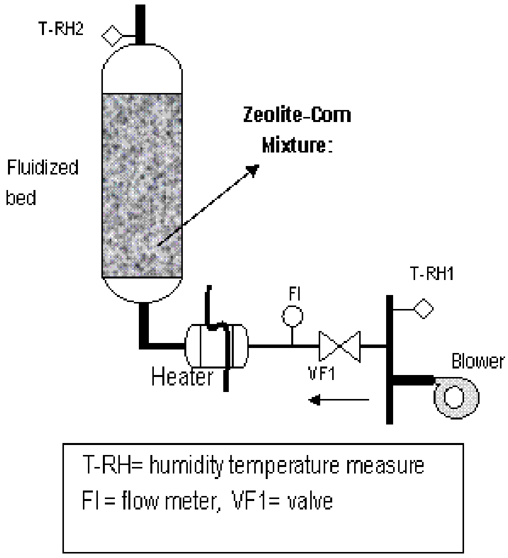

Fig. 2. Fluidized bed mixed-adsorption dryer

The corn was harvested from local farmer in Semarang with initial water content 35-40%. In the first step, Zeolite 3A and corn were mixed in certain zeolite percentage (suppose 25%) with total weigh of 100 gram. The mixture was then fluidized using warm air at 40°C and linear air velocity 4 m/sec. The response, water content in corn was measured every 10 minutes during 2 hours. The drying rate was then calculated refers to the following equation:

$$\frac{dX}{dt} = -k(X - Xe) \qquad (1)$$

The procedure was repeated for percentage of Zeolite 3A 0, 50 and 75%, and operating temperature 30°C (without heating) and 50°C. As comparison, the the natural zeolite was also introduced using similar condition procedures.

RESULT AND DISCUSSION

Effect of Zeolite

Natural zeolite and Zeolite 3A give positive effect on drying corn as indicated in water content during operation. The presence of zeolites can speed up water removal as indicated in Fig.3. For example, at same operational time the water content of corn dried with zeolite is lower than that of without zeolite (zeolite 0%). It means that the zeolite can improve driving force for drying or keep it high by adsorbing water from air as drying medium.

Based on Fig. 3, the type of zeolite gives a bit different improvement where Zeolite 3A is slighty higher than that of natural zeolite. This because, Zeolite 3A has stronger affinity and higher water loaded capacity. However, the usage of natural zeolite is still reasonable for speeding up drying process.

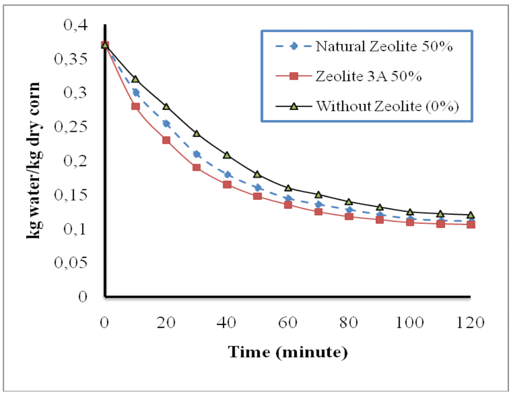

Fig. 3. Comparison of water removal in corn at operational drying 40°C

Effect of zeolite percentage in the mixture

Increasing amount of zeolite can shorten drying time as presented in Table 1. For example, with Zeolite 3A 50% and operating temperature 40°C, the process takes 50 minute for obtaining corn with water content below 15%. The time will be longer as amount of zeolite decreases. Similar phenomena also occurs in natural zeolite (see also Table 1 column 3 and 4). The higher zeolite introduced, the shorter drying time will be obtained. However, in the real application, the introduction of zeolite has to be restricted since it will reduce the dryer capacity.

Table 1. Drying time for corn (from 35% to 15% water content)

Zeolite 3A		Natural Zeolite	
Percentage (%)	Time (minute)	Percentage (%)	Time (minute)
0	80	0	80
25	60	25	70
50	45	50	50
75	35	75	35

Effect of Operating temperature

Temperature takes important role for both desorption and adsorption of water. At higher temperature, equilibroum moisture in materials (zeolite and corn) is lower (Gorbach et al., 2004; Igathinathane et al.,2005). Hence, for drying, higher temperature, higher water can be evaporated from material (see also equation 1). Meanwhile, at adsorption process, lower water can be transferred from air to zeolite (Anonymous, 2008).

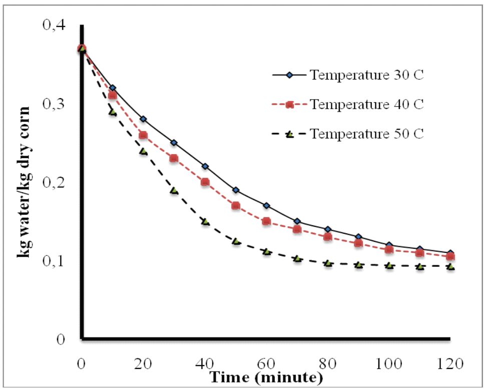

Fig. 4. Water in corn versus time at different operating temperature for Zeolite 3A (25%)

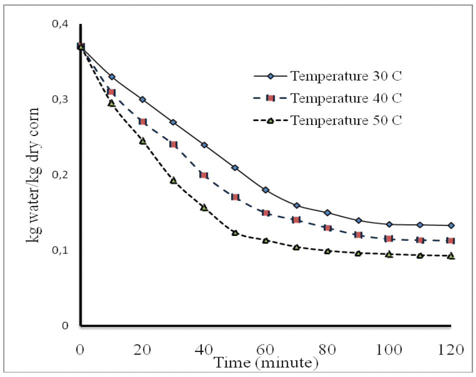

Fig. 5. Water in corn versus time at different operating temperature for natural zeolite (25%)

In mixed-adsorption dryer, both adsorption and desorption takes place simultaneously. Results depcited in Fig. 4 (for Zeolite 3A) and 5 (activated natural zeolite) indicated that the higher temperature, much more water can be evaporated. With increasing air temperature, the relative humidity of air becomes low, and sensible heat of air increases. Thus, the capacity of air to bring water as well as evaporation rate increases. On the other hand, capacity of adsorbents both Zeolite 3A and natural zeolite to load water decreases. In this situation, the performance to improve driving force declines. However, the effect of air temperature, is still dominant. Hence, the water evaporation can be kept high. The same story occurs in activated natural zeolite (see Fig. 5).

Constant of drying rate calculation

Constant of drying rate (*k*) was calculated using equation 1. The results were depicted in Table 2. Similar with common drying process, higher temperature, higher drying rate (see Table 2). The effect of temperature is superior compared to increasing percentage of zeolites. However, the presence of zeolite is still positive to improve drying process for heat sensitive product like corn.

Table 2. value of *k* (1/minute) for Zeolite 3A and natural zeolite

zeolite in mixture(%)	Operating temperature		
	30^{o}C	40^{o}C	50^{o}C
Zeolite 3A			
0	0.0110	0.0127	0.0160
25	0.0112	0.0132	0.0167
50	0.0116	0.0136	0.0180
75	0.0120	0.0141	0.0191
Natural zeolite			
0	0.0110	0.0127	0.0160
25	0.0111	0.0129	0.0161
50	0.0113	0.0131	0.0180
75	0.0117	0.0138	0.0190

CONCLUSIONS

Drying corn was done in fluidised bed dryer with the presence of zeolites. Results indicated that zeolites have given positve effect on drying rate. Increasing amount of zeolite, higher drying rate can be obtained. This research can be a basic consideration for drying corn. However, further research is still required in the aspect of corn quality and energy efficiency.

NOMENCLATURE

X	water in corn	gr H_2O /gr corn
Xe	equilibrium moisture	gr H_2O/gr corn
k	drying rate constant	1/menit
t	time	minute

ACKNOWLEDGEMENTS

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REFERENCES

Ackley M.W, Rege S.U., Saxena H., 2003, Application of Natural Zeolites in The Purification and Separation of Gases, Journal Microporous and Mesoporous Materials 61, 25-42.

Alikhan, Z.; G.S.V. Raghavan; A.S. Mujumdar (1992), Adsorption drying of corn in zeolite granules using a rotary drum. Drying Technology, Vol. 10(3); 783-797

Anonymous (2011), Maize. http://www.wikipedia.org/(accessed May 26, 2011)

Anonymous (2008), *Siliporite data*. CECA and ATO. http://www.cecachemicals.com. (accessed September 26, 2008)

Djaeni, M. (2008), Energy efficient multistage zeolite dryer for heat sensitive products. Doctoral Thesis, Wageningen University, The Netherlands

Djaeni, M.; P.V. Bartels; J.P.M. Sanders.; G. van Straten; A.J.B. van Boxtel (2007), Multistage zeolite drying for energy-efficient drying. Drying Technology, Vol. 25 (6); 1063-1077

Djaeni, M.; P.V. Bartels; C.J. van Asselt; J.P.M. Sanders.; G. van Straten; A.J.B. van Boxtel (2009), Assessment of a two-stage zeolite dryer for energy-efficient drying, Drying Technology, Vol. 27 (11); 1205-1216

Gorbach, A.; M. Stegmaier; G. Eigenberger (2004), Measurement and modeling of water vapor adsorption on zeolite 4A—Equilibria and kinetics. Adsorption, Vol. 10; 29-46

Gruszkiewics M.S., Simonson JM, Burchell TD, Cole DR, 2005, Water Adsorption and Desorption on Microporous Solids at Elevated Temperature, Journal of Thermal Analysis and Calorimetry 81, 609-615.

Igathinathane, C'; A. R. Womac; S. Sokhansanj, L. O. Pordesimo (2005), Sorption equilibrium moisture characteristics of selected corn stover components, American Society of Agricultural Engineers, Vol. 48(4); 1449−1460

Kudra,T. and A.S. Mujumdar (2002), Advanced drying technology, Marcel Dekker Inc., New York, USA

Ratti C. (2001), Hot air and freeze-drying of high-value foods: a review, Journal of Food Engineering, Vol. 49; 311-319

Revilla, G.O.; T.G. Velázquez; S.L. Cortés.; S.A. Cárdenas (2006), Immersion drying of wheat using Al-PILC, zeolite, clay, and sand as particulate media. Drying Technology *24*(8), 1033-1038

Ozkan F.C., Ulku S., 2008, Diffusion Mechanism of Water Vapour in A Zeolitic Tuff Rich in Clinoptilolite, Journal of Thermal Analysis and Calorimetry 94, 699-702.

Senda SP, Saputra H, Sholeh A, Rosjidi M, Mustafa A, 2006, Prospect of Product With Zeolite Application for Slow Release Substance and Membrane, BPPT Bulletin, Indonesia, ISSN 1410-9891

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Web:http://www.fanqun.com/

赞助商（**Sponsor**）

山东天力干燥设备有限公司

Shandong Tianli Drying Equipment Co., Ltd

Web:http://www.kytl.com/

圣泰科红外科技有限公司

Senttech Technology Group

Web:http://www.senttech.cn/

石家庄工大化工设备有限公司

Shijiazhuang Gongda Chemical Equipment Co., Ltd

Web： http://www.gongdagz.com/index.asp

国家干燥技术与设备工程研究中心

National Engineering Research Center of Drying Technology & Equipment

Web:http://www.cthkj.com/

蒙特空气处理设备（北京）有限公司

Munters' Moisture Control Services (MCS) Division

Web： http://www.munters.com/