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Full Length Research Paper

The perception of agricultural researchers about the role of nanotechnology in achieving food security

Seyed Jamal F. Hosseini*, Sahar Dehyouri and Seyed Mehdi Mirdamadi

Islamic Azad University, Science and Research Branch, College of Agriculture and Natural Resources, Tehran, Iran.

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Agricultural researchers in the Province of Isfahan were surveyed in order to explore their perception about role of nanotechnology in food security. The methodology used in this study involved a combination of descriptive and quantitative research and included the use of correlation, regression and descriptive analysis as data processing methods. The total population for this study was 76 agriculture researchers in the Isfahan Province. Data were collected through interview schedules. Based on the results of the mean score, researchers did not agree that nanotechnology could help in achieving food security, although they believed this technology could have more impact on affordability and safety of food products than other dimension of food security. As regression analysis showed, necessary conditions for application of nanotechnology, producing agricultural products, consuming nanotechnology products and constraints in application of nanotechnology caused 21% of variance on the perception of researchers regarding the role of nanotechnology in achieving food security. Based on the perception of respondents, the main constraint in application of nanotechnology in agricultural sector was regulatory constraints.

Key words: Agricultural researchers, nanotechnology, Isfahan Province, food security.

INTRODUCTION

According to the United Nations, about 800 million people in the world are suffering from food shortage and the number of people below poverty line has increased dramatically. New forecasts showed that by 2020 over a billion people would live below poverty line. In the past decades, the emergence of first-generation technology in agriculture leading to green revolution have resulted in the transition from traditional agriculture to industrial agriculture. In this period, quantity and quality of agricultural products improved significantly, although this success was accompanied with excessive use of resources in the agricultural sector (Joseph and Morrison, 2006).

Agriculture is the backbone of most developing countries, with more than 60% of the population relying on it for their livelihood. As well as developing improved systems for monitoring environmental conditions and delivering nutrients or pesticides as appropriate, nanotechnology can improve our understanding of the biology of different crops and thus potentially enhance yields or nutritional values. In addition, it can offer routes to added value crops or environmental remediation.

However, it is evident, more than any time, that there is need for application of new technologies in the agricultural sector. During the last decade, the world witnessed an unprecedented growth in developing nanotechnology. Today, nanotechnology as an interdisciplinary technology can play a leading role in overcoming problems in agriculture. The prediction is that nanotechnology will transform the entire food industry, changing the way food is produced, processed, packaged, transported and consumed (Joseph and Morrison, 2006). Nanotechnology has a wide-range application in all stages of production, processing, storing, packaging and transporting of agricultural products.

Nanotechnology has the potential to revolutionize agriculture and food systems. Agricultural and food systems security, disease treatment delivery system, new tools for molecular and cellular biology, new material for pathogen detection, protection of environment, and education of the public and future workforce are examples of the important links of nanotechnology to the science and engineering of

*Corresponding author. E-mail: jamalfhosseini@yahoo.com. Tel: 00982126540598. Fax: 00982144865474.

agriculture and food systems (Scott and Chen, 2003).

The impact of nanotechnology in the food industry has become more apparent over the last few years. Nanofood is defined as the nanotechnology techniques or tools that are used during cultivation, production, processing and packaging of the food (Joseph and Morrison, 2006).

Currently, one of the major challenges in many developing countries is the issue of food security. Despite the actions taken to reduce world hunger, little progress has been achieved. For example, in developing countries during the last decade, there was only one percent reduction in the number of people who were suffering from malnutrition.

Since the adoption of Millennium Development Goals in September, 2000, implementation of economic reforms to reduce poverty has become a critical strategy in the world. In 2005, a wide range of measures to reduce poverty and hunger has been undertaken in the areas of agricultural development and food production in rural areas. In line with the UN Millennium Development Goals, several new strategies and solutions to reduce hunger, improve productivity in agriculture sector and to change the food chain system has been proposed.

Joseph and Morrison (2006) cited a report from Helmuth Kaiser consultancy (2004) which predicted that the nanofood market will surge from 2.6 to 20.4 billion USD by 2010. This report suggests that with more than 50% of the world population, the largest market for nanofood in 2010 will be Asia. Nanotechnology has a great potential in all aspects of agriculture, processing, packaging and even monitoring of food production and farming activities (FOE, 2008). It can also be applied in plant breeding, production of low risk pesticides and fertilizers, in the field of animal science, food industry and agri-cultural machinery. However the full potential of nano-technology in the agricultural and food industry has still not been realized (Joseph and Morrison, 2006). Scott and Chen (2003) pointed out the role nanotechnology in food security in the United States. For instance, nanotechnology holds the potential that the food supply of United States can be carefully monitored and protected. It is important to point out that producing healthy food and increasing the availability, affordability and accessibility of food for world population now becomes a growing challenge in the coming decades.

Although, agricultural nanotechnology offers tremendous impacts on increasing production and eventually enhancing food security in developing countries, there are numerous challenges, risks, erroneous ideas and beliefs which impede its progress and development. As in the case of any complex technology impacting on wide range of processes and developments, the nature and extent of positive and negative impact will depend on the choice of the technique, place and mode of its application, ultimate use of the product, concerned policies and regulatory measures (Singh, 2000).

In terms of food security, nanotechnology can play an important role in improving the quality and quantity of food produced. Therefore, it is necessary to remove the impediments faced by farmers and provide basic information to enable the spread of nanotechnology. This would enable nanotechnology to be part of a comprehensive development strategy for agricultural sector.

Developing countries such as Iran have adopted their own nanotechnology programs with a specific focus on agricultural applications. The Iranian Agricultural Ministry is supporting a consortium of 35 laboratories working on a project to expand the use of nanotechnology in the agro sector. The ministry is also planning to hold training programs to develop specialized human resources in the field (Joseph and Morrison, 2006).

In the year 2001, the Iran presidential technology cooperation office initiated a smart move in the field of nanotechnology. Through these efforts, nanotechnology gained national priority in the country and in 2003, the Iranian Nanotechnology Initiative was set up with the aim of pursuing the development of nanotechnology in Iran (Iranian Nanotechnology Initiative, 2008). In recent years, Iran has shown a great improvement in the area of nanotechnology especially in publishing ISI papers. At the end of the third quarter of 2009, Iran was ranked 15^{th} having published 919 ISI papers in this field (INIC, 2009).

The attitudes and interests of stakeholders involved in national public debates on the risks and benefits of agricultural technology are having a significant influence on public opinion as well as public policy outcomes in developed and developing countries (Aerni, 2005). Given a key role that agricultural specialists such as researchers in influencing farmers to adopt agricultural innovation, their views on individual innovations may be critical for overall adoption (Wheeler, 2005).

The research question for this study is: what are the perceptions of researchers about the role of nanotechnology on achieving food security? The overall purpose of the study is to examine the perception of researchers about the role of nanotechnology in achieving food security.

MATERIALS AND METHODS

The methodology used in this study involved a combination of descriptive and quantitative research and included the use of correlation, regression and descriptive analysis as data processing methods. The total population for this study was 76 agriculture researchers in the Isfahan Province. Data were collected through interview schedules.

A series of in-depth interviews were conducted with some senior experts in the nanotechnology to examine the validity of questionnaire. A questionnaire was developed based on these interviews and relevant literature. The questionnaire included both open-ended and fixed-choice questions. The open-ended questions were used to gather information not covered by the fixed-choice questions and to encourage participants to provide feedback.

Measuring respondents' attitudes towards role of nanotechnology in food security was achieved largely though structured questionnaire surveys. The final questionnaire was divided into several sections. The first section was designed to gather information about personal characteristics of respondents. The second section was

Table 1. Variables and their measurement scale.

Variable	Measurement scale
Attitudes about role of nano on achieving food security.	Five- point Likert
Impact of nanotechnology on consuming, producing, processing and packaging of agricultural products.	Five- point Likert
Conditions required for application of nanotechnology.	Five- point Likert
Views about constraints.	Five- point Likert

Table 2. Personal characteristics of extension experts.

Sex	Female (14.5%)	Male (85.5%)
Mean age/year	Mean = 40	
Mean work experience/year	Mean = 13	
Degree (%)	Mean = 55.3%	
Occupation status	Permanent (87.4%)	Contractual (12.6%)

Table 3. Means of respondents' views on the role of nanotechnology in achieving food security (1= strongly disagree; 5= strongly agree).

Dimension	Mean
Make food products more affordable	2.60
Make food products more accessible	1.82
Make food products more available	2.15
Make food products safer	2.65

designed to measure the attitudes of researchers about the role of nanotechnology in achieving food security. The respondents were asked to indicate their agreements with 4 statements by marking their response on a five point Likert-type scale. The next section explored the impact of nanotechnology on consuming, producing, processing and packaging of agricultural products and four items were presented in a 5-point Likert format with responses from 1-completely disagree to 5-completely agree. Further section dealt with questions about necessary conditions required for application of nanotechnology in agriculture. Seven attitudes were presented in a 5-point Likert format. The last section was designed to measure the attitudes of researchers about constraints in the adoption of nanotechnology. The respondents were asked to indicate their agreements with six constraints by marking their response on a 5-point Likert-type scale. The variables and their measurement scale are presented in Table 1.

Content and face validity were established by a panel of experts consisting of faculty members at Islamic Azad University, Science and Research Branch and some specialists in the nanotechnology. Minor wording and structuring of the instrument were made based on the recommendation of the panel of experts.

A pilot study was conducted with 20 persons who had not been interviewed before the earlier exercise of determining the reliability of the questionnaire for the study. Computed Cronbach's alpha score was 86.0%, which indicated that the questionnaire was highly reliable.

Dependent variable in the study included achieving food security by application of nanotechnology which was measured by perception of respondents about impact of nanotechnology on four dimensions of food security. The independent variables in this research study were application of nanotechnology and views about constraints in application of nanotechnology. For measurement of correlation between the independent variables and the dependent variable correlation coefficients have been utilized and include Spearman's test of independence.

RESULTS

Table 2 summarizes the demographic profile and descriptive statistics. The results of descriptive statistics indicated that majority of respondents were male with a mean age of 40 years old. More than half of respondents had earned a master degree with major in agriculture and mean average of working experience was 13 years old.

In finding the perception of respondents and their attitudes on the role of nanotechnology in achieving food security, they were asked to express their views. Table 3 displays the respondents' means about the four dimensions of food security. As can be seen, the highest mean number refers to the role of nanotechnology in making food products safer (mean = 2.65) and lowest mean number refers to the role of nanotechnology in making food products more accessible (mean = 1.82).

In order to find the means of respondent's view about the impact of nanotechnology in consuming, producing, processing and packaging the agricultural products, respondents were asked to express their views (Table 4). As can be seen, the highest mean number refers to the impact of nanotechnology on producing agricultural products (mean = 2.70) and lowest mean number refers to the impact of nanotechnology on consuming agricultural products (mean = 2.32). The perception of respondents about the necessary condition required for application of nanotechnology is displayed in Table 5. The highest mean refers to development potential in agricultural sector (mean = 3.25) and the lowest mean refers to public

Table 4. Means of respondents' views about the impact of nanotechnology in consuming, producing, processing and packaging of agricultural products (1= Strongly disagree; 5= strongly agree).

Statement	Mean and standard deviation	
	Mean	SD
Consuming	2.32	0.38
Producing	2.70	0.47
Processing	2.67	0.45
Packaging	2.36	0.40

Table 5. Means of respondents' views about the necessary conditions required for application of nanotechnology in the agricultural sector (1= Strongly disagree; 5=strongly agree).

Condition	Mean	SD
Development potential	3.25	1.047
Private sector participation	1.78	0.645
Production potential	3.14	1.163
Public investment	1.99	0.739
Decreasing the production cost	2.86	1.186
Consumer demands	2.05	1.142
Public awareness	1.57	0.893

awareness about nanotechnology (mean = 1.57).

Table 6 shows the means of respondents' views about the constraints in application of nanotechnology. As can be seen from this table, the highest mean refers to regulatory constraints (mean = 3.96) and the lowest mean to economic constraints (mean = 3.36).

Spearman coefficient was employed for measurement of relationships between independent variables and dependent variable. Table 7 displays the results which show that there is a relationship between perception of respondents on the role of nanotechnology in achieving food security as dependent variable and consuming nanotechnology products; producing, processing and packaging of agricultural products with the necessary conditions required for the application of nanotechnology and constraints as independent variables.

Table 8 shows the result for regression analysis by stepwise method. Independent variables that were significantly related to the perception of respondents about role of nanotechnology in achieving food security were entered. The result indicates that 20% of the variances in the perception of respondents could be explained by the necessary conditions for application of nanotechnology, producing agricultural products, consuming nanotechnology products and constraints in producing nanotechnology products.

Table 6. Means of respondents' views on the constraints in the application of nanotechnology in the agricultural sector (1= Strongly disagree; 5= strongly agree).

Condition	Mean	SD
Educational constraints	3.92	1.004
Managerial constraints	3.92	1.004
Regulatory constraints	3.96	1.026
Environmental constraints	3.77	1.211
Social/cultural constraints	3.39	1.255
Economic constraints	3.36	1.288

DISCUSSION

The perception of researchers about the role of nanotechnology in achieving food security was discussed in this article. Based on the results of the mean score, researchers did not agree that nanotechnology could help in achieving food security, although they believed this technology could have more impact on affordability and safety of food products than other dimension of food security.

With regard to the role of nanotechnology on safety of food products, Dingman (2008) pointed out that many researchers believed that nanotechnology and related food products are safe and causes no harm to human being. As regression analysis showed, necessary conditions for application of nanotechnology, producing agricultural products, consuming nanotechnology products and constraints in application of nanotechnology caused 21% of variance on the perception of researchers regarding the role of nanotechnology in achieving food security. Respondents indicated that in order to achieve food security by adopting nanotechnology as an appropriate technology, necessary conditions should be established over a period of time. Therefore innovative technologies and applications need to be developed that cater specifically to achieve food security.

Considering public awareness, the results show that researchers did not agree on the impact of public involvement in the application of nanotechnology in the agricultural sector of Iran. The reason could be because the nanotechnology in Iran is still in its early phase of development and the findings highlighted the need for informing the public about the importance of nanotechnology.

Nanotechnology has the potential to play a significant role in risk reduction for issues of agriculture and food systems security. The public should be educated in such a way that explains the value-added, increased safety and food security due to application of nanotechnology (Scott and Chen, 2003). A regulatory process should ensure the democratic control of and public participation in decision making on nanotechnology and other new

Table 7. Correlation measures between independent variables and perception of respondents about role of nanotechnology in achieving food security.

Independent variable	Dependent variable	r	P
Consuming nanotechnology products	Role of nanotechnology in achieving food security	0.327**	0.004
Producing agricultural products	Role of nanotechnology in achieving food security	0.411**	
Processing agricultural products	Role of nanotechnology in achieving food security	0.259*	0.026
Packaging agricultural products	Role of nanotechnology in achieving food security	0.416**	0.000
Necessary conditions required for application of nanotechnology	Role of nanotechnology in achieving food security	332	004
Constraints	Role of nanotechnology in achieving food security	0.431**	0.000

*p < 0.05; **p < 0.01.

Table 8. Multivariate regression analysis (role of nanotechnology in achieving food security).

Multivariate regression analysis	B	Beta	T	Sig.
Constant	3.309	--------	6.573	0.000
Necessary conditions for application of nanotechnology	-0.096	-0.378	-2.991	0.004
Producing agricultural products	0.084	0.424	2.879	0.005
Consuming nanotechnology products	-0.081	-0.439	-3.524	0.001
Constraints	0.049	0.320	2.818	0.006

$R^2 = 0.20$; $Y = -0/439x_1 + 0/424x_2 – 0/378x_3 + 0/320x_4$.

technologies. It recommends the initiation of a wide range of participatory processes to enable direct input from the general public into new technology assessment and determination of priorities and principles for public policy, research and development (R and D) and legislation (Johnston et al., 2007).

Like any other new technology, public confidence, trust and acceptance are likely to be the key factors determining the success or failure of nanotechnology applications for the food sector. The nanotechnology derived foods are new to consumers and it remains unclear how public perception, attitudes, choice and acceptance will impact the future of such application in the food sector. It is well known that uncertainties and lack of knowledge of potential effects and impacts of new technologies, or the lack of a clear communication of risks and benefits can raise concern amongst the public (Chaudhry et al., 2008).

Based on the perception of respondents, the main constraint in the application of nanotechnology in the agricultural sector was regulatory constraints. The findings reflect an important fact, namely that a sound regulatory and policy environment is a necessary pre-requisite for developing and adopting of nanotechnology in the agricultural sector.

It is becoming increasingly clear that nanotechnology requires a holistic and tightly integrated regulatory framework for dealing with the range of health, ecological, economic, and socio-political issues that this technology raises (Johnston et al., 2007).

The results demonstrated that the success of nanotechnology in helping to achieve food security will depend on informing the population about the benefits of nanotechnology and its food related products, and in this regard the authorities should provide accurate and on time information. There is no single and appropriate strategy in which nanotechnology could improve the food security and in view of the numerous and varied constraints and opportunities, there is need to develop location-specific strategies.

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