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GAME ANALYSIS OF APPLICATION OF HAZARD ANALYSIS AND CRITICAL CONTROL POINT SYSTEM IN STRAWBERRY RAW MATERIAL PROCESSING INDUSTRY

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ABSTRACT
Food safety has become an outstanding global problem. International food safety hygiene organizations and governments from different countries are taking efforts to establishing a new food safety system to cope with food safety hazards. Hazard analysis and critical control point (HACCP) system is widely applied across the world for its characteristics of prevention, scientificity and systematicness. In terms of economics, this study analyzed the impact of HACCP system on cost-benefit of strawberry raw material processing industry as well as the benefits of implementing HACCP system in strawberry raw material processing industry, in order to provide a theoretical basis for future study. As an effective measure, HACCP system is now the most authoritative safety prevention and monitoring system aiming at food production process. However, its application in food processing enterprises in China is in a slow pace; moreover, the application scope and depth remains to be improved. Thus the application of HACCP in China requires efforts from government, producer and consumer.

1. Introduction

Hazard analysis and critical control point (HACCP) system, the most authoritative safety prevention and monitoring system aiming at food production process, has become the important precondition and security of food consumption and international food commerce (Khatri and Ray, 2007). In recent years, export of Chinese food has not been able to satisfy the international food safety standard. In addition, cost-benefit of HACCP system has not been widely extensively in China. But we can see that, HACCP system developed in the past thirty years has attracted much attention from Chinese scholars for its economical efficiency (Jin et al., 2008). Foreign researches suggested that, developed countries has released regulations and rules concerning HACCP system one after another; forcing implementation of HACCP system aims at ensuring food safety and improving hazard prevention level of food enterprise (Laurian, 2007; Unnevehr et al., 2001; Zaibet, 2000). Meanwhile, most researches has also suggested that, effective implementation and application of HACCP system can bring different levels of profits for food enterprise, which is one of the reasons that middle and large scale food

enterprise positively implementing this system. Furthermore, more and more scholars begin to discuss over and assess the value of HACCP system to enterprise and the whole society with wider research methods (Zhigang et al., 2007; Hooker et al., 2002).

Food is the basis for people's survival and development. Food safety directly concerns the health and safety of thousands of households as well as the development and stability of the society. Foodborne disease, a severe threat for human's health, develops in a serious condition, especially in developing countries and about 21 million people die of foodborne (waterborne) diarrhea (Tim and Sabine, 2006; Thomas and Juan, 2002). This study explored the benefits of HACCP system in terms of economics, in order to analyze the significance of HACCP system more deeply and provide a theoretical support for effective application of HACCP system for strawberry raw material processing industry under the current food production condition.

2. Materials and methods

2.1. Game theory

Game theory, a branch of applied mathematics, has become one of standard analysis tools in economics (Juan and Yadong, 2003). It means two people change their strategies accordingly in an equal game to win.

At first, game theory is mainly used to study and analyze success or failure issue in chess, bridge and gamble. At that time, scholars have only focused on experiential level and have not involved theoretical research. Verification of basic principle of game theory by Von Neumann in year 1928 signified the official birth of game theory. Afterwards, scholars made extension researches on game theory. Based on the information which two participants know about the rival, game theory can be divided into complete information game and incomplete information game. Complete information game means that, two participants exactly know characteristics, strategic space and revenue function of the opposite side, while incomplete information game means two participants do not exactly know characteristics strategic space and revenue function of the opposite side or they do not know accurate information about all characteristics, strategic space and revenue function of the opposite side.

2.2. Related theory about HACCP system

HACCP, a food safety security system based on preventing food safety issues and food safety-related disease, aims at preventing food safety issues and removing or reducing hazards to an acceptable level (Carol et al., 2013). HACCP system is not an independent system; plans about operation specifications and sanitation standard operation procedure are the basis of formulating and implementing HACCP system. HACCP system characterized by rationalization, strong systematicness, strong binding force and high applicability has become the internationally recognized monitoring and controlling system for effectively ensuring food safety and has produced large impact on government monitoring department, consumers and food processing enterprises. This study focuses on its application in strawberry raw material processing industry in economic perspective.

HACCP system is considered as the most effective and economic food safety controlling and monitoring system by the world. HACCP system can reduce and lower biological, chemical and physical pollution in the process from raw materials to consumption (William, 2014). Implementation of HACCP system further perfects food quality monitoring system in China. To be specific, it supplements the traditional food quality monitoring system, which makes food safety monitoring process more scientific and reasonable. Practical operation in enterprises suggested that, it is too late to remedy if we test the product at the last step of production, as the unqualified products have been formed. Such kind of responsive monitoring mode has not been able to satisfy the constantly improved production needs and cannot ensure food safety as well.

2.3. Theory of cost-benefit analysis

Cost is a category of value in commodity economics and also a component of commodity value. Production is bound to consume some resources and the monetary expression and objectification of the consumed resources is termed as cost (Els and Luca, 2014). Benefit, a concept corresponding to cost, refers to the contributions on system, including direct benefits and direct benefits. Benefit differs in meaning if we recognize benefits in different views. Cost-benefit analysis is one of the commonly used economical analysis methods. Managers from enterprises tend to use cost benefit to analyze and confirm operating target and scheme, i.e., calculating and assessing the cost and benefit of every possible scheme as well as the limitation conditions and probability of scheme implementation and then choosing the most beneficial one.

Generally speaking, cost and benefit is opposite and unified. In the case of unchanged index, reducing cost would increase benefits; however, when all economical indexes change, the ratio of benefit and cost must be increased, in order to improve benefits. Indeed, absolute volume of some necessary cost is possible to increase accordingly. But such increasing is aiming at obtaining greater benefit increase and cannot ignored compared to benefit increase.

3. Results and Discussions

3.1. Game analysis of food processing enterprise and local government

Strawberry raw material processing industry, one party of game, would compare the cost and benefit in the condition of implementing or not implementing HACCP system, while government, the other party, would also consider whether it should monitor safety production of strawberry raw material processing industry as well as how much monitoring strength can maximum the benefit. Government would also balance the cost and benefits if the monitoring is carried out in strawberry raw material processing industry and then choose the optimal decision based on that.

Table 1. Impact on cost and benefits if HACCP system is applied in strawberry raw material processing industry

Index	Perception of enterprise (%)					Tot（%）	Sample size
	1	2	3	4	5		
Production cost	1	50	40	5	0	100	20
Sales revenue	1	20	45	30	0	100	20
Trading profit	10	50	30	5	0	100	20
Ratio of profits to cost	10	45	30	10	0	100	20
Return on total assets	10	35	30	20	0	100	20
Return on net assets	1	45	25	25	0	100	20
Security surplus cash multiples	5	35	35	20	0	100	20
Growth rate of sales revenue in three years	1	50	25	20	0	100	20
Growth rate of assets in three years	5	35	25	30	0	100	20
Technical input ratio	20	35	30	10	0	100	20

Every index ranges from 1 to 5. The value stands for the increase of cost or benefit perceived by strawberry raw material processing industry after HACCP system implementation. 1 refers to no impact and 5 refers to maximum impact. 1 = no increase, 2= little increase, 3= a little increase, 4= much increase, 5=numerous increase.

Enterprises' perception on cost and benefits after HACCP implementation has been shown

in Table 1. Willing strength of HACCP system implementation of strawberry raw material processing industry is not only correlated to the punishment strength on strawberry raw material processing industry due to irregular production, but also correlates to the monitoring strength of local government to strawberry raw material processing industry.

Moreover, monitoring strength is correlated to the implementation degree of HACCP system in strawberry raw material processing industry as well as the loss. As to the game relationship between local government and strawberry raw material processing industry, strawberry raw material processing industry balances in the view of the impact of HACCP implementation on net benefits of enterprise and the impact of monitoring of local government on cost. Strawberry raw material processing industry would balance the extra benefits obtained from producing unsafe food and benefits brought by implementing food safety systems such as HACCP system. In the eye of most enterprise, the former is larger than the latter. They believe that, implementing HACCP system means continuous cost input which may increase the burden of enterprise and decrease profits and benefits. Therefore, strawberry raw material processing industry tends to acquire maximum benefits without implementing HACCP system and even producing foods illegally.

3.2. Game analysis of strawberry raw material processing industry and consumer

This study attempts to analyze the game relationship between product quality and price based on the previous studies. Product quality is defined as quality of safety.

3.2.1 Analysis of market demand of food in different quality

Here, we assume the demand of customers on a food in market as:

$$C = \begin{cases} \theta q - r \\ 0 \end{cases} \tag{1}$$

Where q refers to quality characteristics parameter of food, θ (θ>0) refers to the effectiveness obtained when q=1 (θ is the quality preference coefficient of customers), $\theta q - r$ stands for customer surplus. Assume θ as a random variable. The effectiveness obtained by customers is greater when θ is larger. Meanwhile F(θ) is used to express distribution function of θ and $f(\theta)$ is used for express its density function.

There are two foods in same category but in different quality q1 and q_2 ($q_1 > q_2$). q_1 is the quality of product A produced by strawberry raw material processing enterprise which has applied HACCP system, while q_2 is the quality of product B produced by strawberry raw material processing enterprise B which has not applied HACCP system. We assume $0 < q_1 < \bar{q}$ and $r_1 > r_2$. When $\theta q_2 > r_2$, customers prefer to purchase product A. That is because

$$\begin{aligned} (\theta q_1 - r_1) - (\theta q_2 - r_2) &= p_1(\theta \frac{q_1}{r_1} - 1) - r_2(\theta \frac{q_2}{r_2} - 1) \\ &\geq r_1(\theta \frac{q_2}{r_2} - 1) - p_2(\theta \frac{q_2}{r_2} - 1) \\ &= (r_1 - r_2) \quad (\theta \frac{q_2}{r_2} - 1) > 0 \end{aligned} \tag{2}$$

It can be seen that $C_1 > C_2$. Customers prefer to purchase product A produced by enterprise A which has implemented HACCP system. Then we come to consider the condition when $\frac{q_1}{r_1} \leq \frac{q_2}{r_2}$. We assume demand on two products has no difference, i.e., $C_1 = C_2$, when the quality selection of customers is $\bar{\theta}$. Thus we get:

$$\bar{\theta} q_1 - r_1 = \bar{\theta} q_2 - r_2, \bar{\theta} \square q = \square r, \quad (\square q = q_1 - q_2, \square r = r_1 - r_2) \tag{3}$$

$$\bar{\theta} = \frac{\Delta q}{\Delta r} \tag{4}$$

Necessary and sufficient condition for customer purchasing product A is $C_1 > C_2$ and $\theta \geq \frac{r_1}{q_1}$ or $\theta \geq \bar{\theta} = \frac{\Delta r}{\Delta q}$ and $\theta \geq \frac{r_1}{q_1}$. When $\frac{q_1}{r_1} \leq \frac{q_2}{r_2}$, then we

get $\frac{\square r}{\square q} \geq \frac{r_1}{q_1} \geq \frac{r_2}{q_2}$. This is because $\frac{\square r}{\square q} \geq \frac{r_1}{q_1} \geq \frac{r_2}{q_2}$ is equal to $q_1 \square r \geq r_1 \square q$ and meanwhile $q_1 r_2 \leq r_1 q_2$, .

Thus demand of customer on product A is:

$$r\left\{\theta \geq \frac{r_1}{q_1}, \theta \geq \frac{r_1 - r_2}{q_1 - q_2}\right\} = 1 - F\left(\frac{\square r}{\square q}\right) \square D_1(r_1, r_2, r_1, r_2) \quad (5)$$

Similarly, customers would purchase product B only when $U_1 \leqq U_2$, $\theta \geq \frac{r_2}{q_2}$。 or $\theta \leq \frac{\square r}{\square q}$, and $\theta \geq \frac{r_2}{q_2}$, thus demand on product B is:

$$r\left\{\frac{r_2}{q_2} \leq \theta \leq \frac{\square r}{\square q}\right\} = F\left(\frac{\square r}{\square q}\right) - F\left(\frac{r_2}{q_2}\right) \square D_2(r_1, r_2, r_3, r_4) \quad (6)$$

Then we can get demand functions of two products:

$$\begin{cases} D1(q_1, q_2, r_1, r_2) = 1 - F(\frac{\square r}{\square q}) \\ D_2(q_1, q_2, r_1, r_2) = F\left(\frac{\square r}{\square q}\right) - F(\frac{\square r_2}{\square q_2}) \end{cases} \quad (7)$$

When θ even distributes on [0, 1], we have

$$\begin{cases} D1(q_1, q_2, r_1, r_2) = 1 - \frac{r_1 - r_2}{q_1 - q_2} \\ D2(q_1, q_2, r_1, r_2) = \frac{r_1 - r_2}{q_1 - q_2} - \frac{r_2}{q_2} \end{cases} \quad (8)$$

$\frac{1}{q_1 - q_2}$ is the competitiveness strength of enterprise A.

From formula (8), we know that, demand of customers decreases when price of product rises; moreover, demand of customer rises when the price of product of the other enterprise becomes higher. If price of two products is the same, then demand of product A would rise with the improvement of product quality and declines with the quality improvement of product B.

3.2.2. Quality and price competition

Quality-price competition game model is three-stage and dynamic (Langfeng and Hanhui, 2008). In stage 1, enterprise A chooses quality q_1; enterprise B chooses quality q_2 in stage 2; and in stage 3, both enterprises choose price. Game structure is shown in Figure 1.

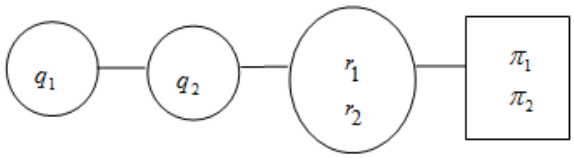

Figure 1. Three-stage dynamic game structure

4. Conclusions

There are two game relationships involving in the application of HACCP system in strawberry raw material processing enterprise. First is the game relationship between local government and food enterprise and the second is the game relationship between food enterprise and customers. In the second game relationship, quality and price are the key points. Customers prefer high quality and low price food. They would give priority to high quality food, *i.e.,* safe food. Application of HACCP system is bound to produce impact on cost and benefit of enterprises. Moreover, we find through game analysis that, application of HACCP system is beneficial to government, enterprise and customers, especially market development of enterprise.

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