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Research Article

Performance Evaluation Model for Product Quality Control of Vegetable Cooperatives

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Abstract: The purpose of this study is to investigate the product quality control performance of vegetable cooperatives in China, using Heilongjiang province as a case. This study applies fuzzy integral theory to develop a comprehensive evaluation model and analyzes the product quality control performance of the vegetable cooperatives. The results show that the performance of vegetable cooperatives in the production process is the highest. That is, vegetable cooperatives have important effect on the performance of product quality control mainly in the production process. Through the large-scale operation and the implementation of standardized production, vegetable cooperatives can effectively transform the decentralized production into the unified production. To exert the role of vegetable cooperatives in the product quality control, the incentive systems and the financial support policies should be improved and actively implement the brand strategy.

Keywords: Cooperatives quality control, performance evaluation, vegetable safety

INTRODUCTION

As one of the most important industries organization and institutional arrangements, there are about 1/3 the world's food production managed and dominated by agricultural cooperatives (Pattison, 2000). More and more scholars recognize that agricultural cooperatives, as a special institutional resources, is a kind of the third sector which in parallel with the public sector and the private sector in the development of society and economy. They found that cooperatives have an important impact on product quality. Based on a comparative model, Herbst and Prufer (2007) found that the product quality level of non-profit organization is the highest, followed by cooperative organizations; the lowest is that of enterprise. Drivas and Giannakas (2010) uses game model to analyze the investment decision and innovation behavior of quality improvement. The results show that the cooperatives, which pursuit maximum benefits of membership, more willing to invest in quality improvement than that of IOF. From the perspective of quality competition, some scholars from the perspective analyzed the quality product strategy of cooperative and IOF (Fulton and Sanderson, 2002; Saitone and Sexton, 2009).

Most domestic literature discussed the agricultural products safety on the base of the relations of the government and the market. That is, the realization of agricultural products safety ensured depends on the role of market and government (Wang and Xu, 2005). Gong-kui and Rui-Yao (2004), Ying-heng (2004), Jie-hong and Li-Qing (2004) and Zhi-Ying (2006) analyzed the impact of consumer behavior on food safety based on the consumer recognition, acceptance and willingness to pay. De-Yi and Hai-Juan (2002) and Xiu-Qing and Yun-Feng (2002) think that the problem of edible agricultural products safety should be solved by government supervision.

In view of the government and market mechanisms are likely to failure in the vegetable safety governance, a growing number of domestic scholars recognize cooperatives is the third sector in social and economic development parallel with the public sector and private sector. Cooperatives are the alternative choice to socially vulnerable in the field of market failures or government regulation is not completely effective. They recognized that cooperatives are a mixed industrial organization between the bureaucratic organization and the market organization (Zu-Hui, 2008).

One of the important reasons is that the more complex production process or the higher cost of quality testing and monitor (Lin and Yan-Li, 2006). People's attention is aroused by the impact of cooperatives on agricultural operations scale. The establishment of cooperatives promote the development of farmer organization and operation scale (Xue-Dong, 2008; Gui-Yin, 2009). The above literatures have provides good research perspective for the further study. However, few domestic literatures analyzed the relationship between the cooperatives and agricultural

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products safety. Based on the existing research, the main purpose of the study is to develop an evaluation model and analyze the product quality control performance of vegetable cooperatives.

COMPREHENSIVE EVALUATION MODEL

Determine the value of the evaluation indicators:

- **The value of indicators given by the expert scoring:** f_1 refers to the indicators values set. Its value can be obtained through the questionnaire. As shown in Table 1:

$$g_\lambda(\{fX_i^k, X_2^k\}), g_\lambda(\{X_2^k, X_3^k\}), \ldots,$$
$$g_\lambda(\{X_1^k, X_2^k, X_3^k\}), \ldots, g_\lambda(\{X_1^k, X_2^k, \ldots, X_{n-1}^k\}), \ldots,$$
$$g_\lambda(\{X_1^k, X_2^k, \ldots, X_n^k\})$$

$$\tilde{f}1 = \left\{ \tilde{f}_j(X_i^k), k = 1, \ldots, n; i = 1, \ldots, dn_k; j = 1 \ldots, m \right\}$$

where,

$\tilde{f}_j(X_i^k)$ = To the value of X^k_i which given by expert *j*

X^k_i = To the indicator *j* which belongs to the evaluation level X_k

$\tilde{f}_j(X_i^k)$ = The trapezoidal fuzzy number be expressed as: $(a_i^k, b_i^k, c_i^k, d_i^k), a_i^k \in [0,1], b_i^k \in [0,1], c_i^k \in [0,1], d_i^k \in [0,1]$

n = To the number of evaluation level

dn_k = The number of indicators of evaluation level X_k

m = The number of experts

- **To calculate the fuzzy values of indicators:** Apply fuzzy algorithm to calculate the fuzzy values of indicators set f, according to expert advices:

$$\tilde{f}(X_i^k) = \frac{1}{m} \otimes \left\{ \tilde{f}_1(X_i^k) \oplus \tilde{f}_2(X_i^k) \oplus \ldots \oplus \tilde{f}_m(X_i^k) \right\} \tag{1}$$

$$M_3(f(X_i^k)) = \begin{cases} a_i^k ; a_i^k = b_i^k = c_i^k = d_i^k \\ \dfrac{(d_i^k)^2 + (C_i^k)^2 - (b_i^k)^2 - (a_i^k)^2 + C_i^k d_i^k - a_i^k b_i^k}{3(d_i^k + C_i^k - b_i^k - a_i^k)} \end{cases}$$

$$\tilde{f} = \left\{ \tilde{f}(X_i^k); k = 1, \ldots, n; i = 1, \ldots, dn_k \right\}$$

where,

$\tilde{f}(X_i^k)$ = To the fuzzy value of the indicator *i* under the evaluation level X_k

$\otimes$, $\oplus$ = To the fuzzy operator

- **The exact value can be obtained by the defuzzification operation:** We apply the relative distance formula (M1), the center value (M2) and the gravity value (M3) to converted the fuzzy values into of the exact values. $f(X^k_i)$ refers to the fuzzy values of the qualitative indicator *I* under the evaluation level X_k. We can converted $f(X^k_i)$ into the exact values of $f(X^k_i)$, according to the following equation:

Table 1: The evaluation value of linguistic variable

Linguistic variable	Value
Extreme poor	(0 ,0, 0, 0)
Very poor	(0, 0, 0.1, 0.2)
Poor	(0.1, 0.2, 0.2, 0.3)
Slightly poor	(0.2, 0.3, 0.4, 0.5)
Average	(0.4, 0.5, 0.5, 0.6)
Slightly better	(0.5, 0.6, 0.7, 0.8)
Good	(0.7, 0.8, 0.8, 0.9)
Better	(0.8, 0.9, 1, 1)
Best	(1, 1, 1, 1)

$$f(X_i^k) = \frac{M_1(\tilde{f}(X_i^k)) + M_2(\tilde{f}(X_i^k)) + M_3(\tilde{f}(X_i^k))}{3} \tag{2}$$

where,

$$M_1(\tilde{f}(X_i^k)) = \frac{d_i^{k'}}{d_i^{k'} + d_i^{k*}}$$
$$(i = 1, \ldots, dn_k) \tag{3}$$

$$d_i^{k'} = \sqrt{\frac{1}{4}((a_i^k)^2 + (b_i^k)^2 + (c_i^k)^2 + (d_i^k)^2)}$$
$$d_i^{k*} = \sqrt{\frac{1}{4}\left[(1-a_i^k)^2 + (1-b_i^k)^2 + (1-c_i^k)^2 + (1-d_i^k)^2\right]} \tag{4}$$
$$M_2(\tilde{f}(X_i^k)) = \frac{(b_i^k + c_i^k)}{2} + \frac{(d_i^k - c_i^k) - (b_i^k - a_i^k)}{6} = \frac{2b_i^k + 2c_i^k + d_i^k + a_i^k)}{6}$$

$$M_3(f(X_i^k)) = \begin{cases} a_i^k ; a_i^k = b_i^k = c_i^k = d_i^k \\ \dfrac{(d_i^k)^2 + (C_i^k)^2 - (b_i^k)^2 - (a_i^k)^2 + C_i^k d_i^k - a_i^k b_i^k}{3(d_i^k + C_i^k - b_i^k - a_i^k)} \end{cases} \tag{5}$$

The exact values of all indicators can be obtained by the following equation:

$$\left\{ f(X_i^k) \mid k = 1, \ldots, n; i = 1, \ldots, dn_k) \right\}$$

Determination of the fuzzy density:

- **The linguistic values of fuzzy density of evaluation indicators:** We can calculate the linguistic values of fuzzy density of evaluation indicators based on the comprehensive analysis of expert opinions. As shown in Table 2.

$$\tilde{g}1 = \left\{ \tilde{g}_j(X_i^k), k = 1, \ldots, n; i = 1, \ldots, n_k; j = 1 \ldots, m \right\}$$

$\tilde{g}_j(X_i^k)$ refers to trapezoidal fuzzy values, that is, $(a_i^k, b_i^k, c_i^k, d_i^k), a_i^k \in [0,1], b_i^k \in [0,1], c_i^k \in [0,1], d_i^k \in [0,1]$

$\tilde{g}_j(X_i^k)$ refers to the linguistic values of indicator *i* under evaluation layer X_k which given by expert *j*. *n*

Table 2: Linguistic variable of fuzzy density

Linguistic variable	Values
Trifling importance	(0, 0, 0, 0)
Very unimportant	(0, 0, 0.1 ,0.2)
Unimportant	(0.1, 0.2, 0.2, 0.3)
Slightly unimportant	(0.2, 0.3, 0.4, 0.5)
Average	(0.4, 0.5, 0.5, 0.6)
Slightly important	(0.5, 0.6, 0.7, 0.8)
Important	(0.7, 0.8, 0.8, 0.9)
Very unimportant	(0.8, 0.9, 1, 1)
High importance	(1, 1, 1, 1)

refers to the number of evaluation layers, n_k the number of indicators under evaluation layer X_k, m the number of experts.

- To calculate fuzzy values of fuzzy density of indicators according to experts' advices, the fuzzy value set of fuzzy density of indicators can be obtained based on the calculation of linguistic values of fuzzy density g1.
- The accurate value of fuzzy density can be obtained by fuzzy calculating.

The value of fuzzy density can be obtained by the defuzzification operation

$g = \{g(X_i^k), k = 1,\ldots,n; i = 1,\ldots,n_k\}$, $g(X_i^k)$ refers to the fuzzy density values of indicator i under evaluation layer X_k.

To calculate the evaluation value:

- To value of λ, according to the genetic algorithms:

According to the value of fuzzy density, $g = \{g(X_i^k), k = 1,\ldots,n; i = 1,\ldots,n_k\}$, apply the genetic algorithms on the base of the ranking to optimized calculation:

$$\min \left| 1 - \frac{1}{\lambda_k}\left[\prod_{i=1}^{n_k} (1 + \lambda_k g(X_i^k)) - 1\right]\right|$$
$$s.t. -1 < \lambda < \infty$$

So, we can obtain the value of each evaluation level X_k: $\lambda = \{\lambda_k (k = 1,\ldots,n)\}$

- To calculate the fuzzy value under every evaluation level X_k:

$$g_\lambda(\{X_1^k, X_2^k\}), g_\lambda(\{X_2^k, X_3^k\}),\ldots,$$
$$g_\lambda(\{X_1^k, X_2^k, X_3^k\}),\ldots, g_\lambda(\{X_1^k, X_2^k,\ldots, X_{n-1}^k\}),\ldots,$$
$$g_\lambda(\{X_1^k, X_2^k,\ldots, X_n^k\})$$

- **Sorting of indicator values:** To reorder the indicator values, fX_i^k (i = 1, …, n_k), under the evaluation level X_k on the base of descending:

$$f(X_{i_1}^k) \geq \ldots \geq f(X_{i_j}^k) \geq \ldots \geq f(X_{i_{nk}}^k)$$
$$\left(\{i, | j = 1\ldots, nk\} = \{i | i = 1,\ldots, nk\}\right)$$

- **To calculate evaluation value:** $f(X_k)$ refers to the values of evaluation layer X_k. We apply fuzzy integral to calculate the values of the evaluation levels:

$$\begin{aligned} f(X_k) &= f(X_{i_{nk}}^k) g_\lambda(\{X_{i_1}^k, X_{i_2}^k,\ldots, X_{i_{nk}}^k\}) + \ldots + f(X_{i_2}^k) \\ &- f(X_{i_3}^k) g_\lambda(\{X_{i_1}^k, X_{i_2}^k\}) + f(X_{i_1}^k) - f(X_{i_2}^k) g_\lambda(X_{i_1}^k) \end{aligned} \quad (6)$$

Repeat indicator values sorting and calculate the value of all evaluation levels:

$$f = \{f(X_k)\}(k = 1,\ldots,n)$$

Comprehensive evaluation: Apply linear weighting method to calculate the comprehensive evaluation value V:

$$V = \sum_{k=1}^{n} f(X_k) w(X_k)$$

where,

$f(X_k)(k = 1,\ldots,n)$ = To the value of every evaluation level
$w(X_k)(k = 1,\ldots,n)$ = The weight value of every evaluation level

A CASE STUDY IN HEILONGJIANG PROVINCE, CHINA

The establishment of hierarchical structure: We sent out questionnaires for 120 managers and experts who worked in 13 typical vegetable cooperatives and 8 universities In Heilongjiang Province. A complex problem is decomposed into easy-to-description indicators layer by layer. According to the principle of AHP and combined with the characteristics of vegetable cooperatives product safety control, the target layer is composed of the several evaluation layers and each evaluation layer was composed of several indicators layer.

The evaluation indicators system of vegetable cooperatives product safety control mechanisms is shown in Table 3. *A* refers to the evaluation indicators system of vegetable cooperatives product safety control mechanisms.

Members and evaluation methods: Members of fuzzy evaluation including managers and experts those come from the department of agriculture administrative, vegetable cooperatives and universities. We can calculate the various types of indicators value based on

Table 3: The system of evaluation indicators

Target layer	Evaluation layer	Indicators layer
A	Member's goals B_1	Profit maximization C_{11}
		Sustainable growth C_{12}
		Social responsibility C_{13}
	Market demand B_2	Green vegetables demand C_{21}
		Organic vegetables Demand C_{22}
		Pollution-free vegetables demand C_{23}
	Policy B_3	Macro-management policies C_{31}
		Quality management policies C_{32}
	Production Process B_4	Harmonization procurement C_{41}
		Production safety technology C_{42}
		Training of member C_{43}
		Large-scale production C_{44}
		Unified production standards C_{45}
	Sales process B_5	Farmer-Supermarket Direct-Purchase C_{51}
	Brand certification B_6	The number of green food certification C_{61}
		The number of pollution-free food certification C_{62}
		The number of organic food certification C_{63}

Table 4: Linguistic values of levels evaluation indicators and fuzzy density

	indicators layer	Linguistic values of the indicators	Linguistic values of the fuzzy density
Member's goals	Profit maximization	(0.55, 0.76, 0.93)	(0.73, 0.93, 1.00)
	Sustainable growth	(0.54, 0.74, 0.91)	(0.72, 0.92, 0.99)
	Social responsibility	(0.46, 0.66, 0.85)	(0.68, 0.89, 0.93)
	The overall level	---	(0.71, 0.91, 0.97)
Market demand	Green vegetables demand	(0.51, 0.72, 0.89)	(0.69, 0.89, 0.97)
	Organic vegetables Demand	(0.50, 0.71, 0.88)	(0.60, 0.80, 0.92)
	Pollution-free vegetables demand	(0.47, 0.67, 0.82)	(0.62, 0.82, 0.93)
	The overall level	---	(0.64, 0.84, 0.94)
Policy	Macro-management policies	(0.56, 0.75, 0.93)	(063, 0.83, 0.96)
	Quality management policies	(0.57, 0.78, 0.94)	(0.64, 0.85, 0.96)
	The overall level	---	(0.63, 0.84, 0.96)
Production Process	Harmonization procurement	(0.48, 0.68, 0.88)	(0.6, 0.88, 0.98)
	Production safety technology	(0.43,0.62, 0.81)	(0.53,0.73, 0.90)
	Training of member	(0.56,0.75, 0.93)	(0.62, 0.82, 0.96)
	Large-scale production	(0.51,0.72, 0.91)	(0.65, 0.85, 0.97)
	Unified production standards	(0.51,0.71, 0.90)	(0.62, 0.83, 0.96)
	The overall level	---	(0.62, 0.82, 0.94)
Sales process	Farmer-Supermarket Direct-Purchase	(0.60, 0.80, 0.90)	(0.60, 0.80, 0.90)
Brand certification	The number of green food certification	(0.56, 0.76, 0.92)	(0.67, 0.87, 0.99)
	The number of pollution-free food certification	(0.53, 0.73, 0.89)	(0.61, 0.81, 0.93)
	The number of organic food certification	(0.54, 0.74, 0.90)	(0.62, 0.82, 0.96)
	The overall level	---	(0.63, 0.83, 0.95)

Table 5: The value of indicators were obtained by fuzzy calculating

	Indicators layer	Linguistic values of the indicators	Linguistic values of the fuzzy density
Member's goals	Profit maximization	0.75	0.87
	Sustainable growth	0.73	0.86
	Social responsibility	0.66	0.74
	The overall level	--	0.85
Market demand	Green vegetables demand	0.71	0.85
	Organic vegetables Demand	0.70	0.77
	Pollution-free vegetables demand	0.65	0.79
	The overall level	--	0.83
Policy	Macro-management policies	0.75	0.81
	Quality management policies	0.76	0.82
	The overall level	--	0.82
Production Process	Harmonization procurement	0.68	0.85
	Production safety technology	0.62	0.84
	Training of member	0.75	0.80
	Large-scale production	0.71	0.82
	Unified production standards	0.71	0.80
	The overall level	--	0.89
Sales process	Farmer-Supermarket Direct-Purchase	0.80	0.80
Brand certification	The number of green food certification	0.75	0.84
	The number of pollution-free food certification	0.72	0.78
	The number of organic food certification	0.73	0.80
	The overall level	--	0.81

Table 6: Fuzzy integral value

	Set	λ value	λ Measure values
Member's goals	$\{C_{11}\}$	0.95	0.87
	$\{C_{11},C_{12}\}$		0.89
	$\{C_{11}, C_{12}, C_{13}\}$		0.90
Market demand	$\{C_{21}\}$	0.96	0.85
	$\{C_{21},C_{22}\}$		0.92
	$\{C_{21}, C_{22}, C_{23}\}$		0.95
Policy	$\{C_{31}\}$	0.96	0.81
	$\{C_{31},C_{32}\}$		0.86
Production Process	$\{C_{41}\}$	0.98	0.85
	$\{C_{41},C_{42}\}$		0.92
	$\{C_{41},C_{42}, C_{43}\}$		0.93
	$\{C_{41},C_{42}, C_{43}, C_{44}, C_{45}\}$		0.95
	$\{C_{41}, C_{42}, C_{43}, C_{44}, C_{45},C_{46}\}$		0.96
Sales process	$\{C_{51}\}$	0.97	0.80
Brand certification	$\{C_{61}\}$	0.97	0.84
	$\{C_{61},C_{62}\}$		0.88
	$\{C_{61}, C_{62}, C_{63}\}$		0.91

Table 7: The overall performance value of fuzzy integral value

	Weights	Integral value	The overall performance value
Member's goals	0.85	0.85	0.842
Market demand,	0.83	0.87	
Policy	0.82	0.80	
Production process	0.89	0.90	
Sales process	0.80	0.77	
Brand certification	0.81	0.86	

the comprehensive analysis of expert opinions. As shown in Table 4.

The value of evaluation indicators can be obtained by fuzzy calculating. As shown in Table 5.

The fuzzy integral value can be obtained by calculating. As shown in Table 6.

While, the highest value is the level of production process (0.90), the lowest value of sales process level (0.77). Sequentially arranged from high to low: production process, market demand, brand certification, member goals, policy and sales process. The overall performance expressed by the weighted average. That is, the integral value multiplied by weight values of the levels and then, the overall performance value is 0.842. As shown in Table 7.

CONCLUSION

Based on the linguistic variables and improved evaluation model for fuzzy integral, we develop an improved comprehensive evaluation method. The empirical studies have shown that the performance of the membership goals is 0.85, market demand 0.87, policy motivation 0.80, the production process 0.90, the sales process 0.77 and the brand certified 0.86. Where, the production process performance is the highest and the lowest is the sales process performance. To sort the influencing factors of product safety control performance of vegetable cooperatives: production process, market demand, brand certification, member's goals, policies motivation, sales process.

In recent years, the domestic increasingly concerned about vegetables safety. The government departments have issued a series of policies, increased the regulatory intensity and formed the external policy environment. However, the above analysis shows that as for the various influencing factors, production process is essential. Through the large-scale operation and the implementation of standardized production, vegetable cooperatives can effectively transform the decentralized production into the unified production.

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