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Empirical Prediction and Risk Assessment of Chicken Egg Prices in China Using Support Vector Machine Algorithm

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ABSTRACT
The study was aimed to predict and assess the prices and their corresponding fluctuations of chicken eggs in China with risk warning using Support Vector Machine (SVM) algorithm from the aspects of cost, supply and demand. Through correlation analysis, five crucial influencing factors were chosen in the prediction and the assessment of chicken egg prices. Next, six different SVM models were established and tested with the corresponding optimized parameters and training input datasets collected during 2006-2012 in China. The predicted accuracies of five models was proved to be more than 80% and only one model was 50% by comparison with the actual risk warning values of chicken egg price fluctuations. Specifically, the predicted accuracies of two models were 100%. From the results of these SVM models, it was also inferred that the customer satisfaction index was relatively insignificant, while the cost and demand influencing factors were significant for predicting the prices and their fluctuations of chicken eggs.

Key words: Price fluctuation, risk assessment, chicken eggs, support vector machine

INTRODUCTION
Egg is regarded as one of the most popular sources of human food and nutrition. Particularly, chicken eggs contain large amounts of nutriments that have the effects of promoting intelligence growth, protecting liver, anti-aging and anti-cancer, such as proteins, vitamins and minerals for human development and health. Actually, the consumption of chicken eggs is rising with the constant improvement of people's income levels and living standards in China. For instance, there was a statistics of 300 chicken eggs for Chinese annual per capita consumption in 2010, which was more than those of the United States, Canada and other developed countries. There was not only a huge consumption of chicken eggs but also the most output of global chicken eggs in China for many years. In fact, China is one of the world's largest egg producers. For example, the national total output of chicken eggs in 2010 was 28 million tons which was about 10.16 times of that in 1980. The yield of Chinese chicken eggs could account for over 40% of the total global share in 2010. As one of the commonly eaten food and nutrition sources every day, the consumer is very sensitive to the egg price changes and/or fluctuations in the markets. Furthermore, the price fluctuations of chicken eggs affect peculiarly the producers and business operators and their enterprises. It is of great significance for the practical production, sales and management of chicken eggs. However,

the coordination and supervise degrees are not high yet in the regulatory sectors, combined with the separation of the market information in urban and rural areas, in which the mutual blockade price information phenomenon appears and exists. However, the national egg market in China is still in the primary stage of development. In such circumstances, there are frequently misjudgments, erroneous decision-making and even misunderstandings among consumers, producers and operators, because of the information asymmetry and inaccurate communication. Thus, the great price fluctuations in chicken egg markets appeared that often bring irreparable losses to residents, farmers and their enterprises and generate serious impacts on government management sectors, the market of agricultural products and even the whole national economy. Meanwhile, the economic wave is usually utilized to describe the changing variables of time series (e.g. prices) and the price fluctuation is generally referred to the ongoing movement of the absolute price or relative price of a commodity. The first study on the price fluctuation was reported by Adam Smith, who thought that market supply and demand were the main causes of price variability (Bak *et al*., 1993). Later, David Ricardo developed the price theory of Adam Smith, who made it clear that supply and demand was the important affecting factors rather than the determining factors of price fluctuation (Bak *et al*., 1993). Since then, many scholars are interested in the issues of price fluctuations.

Nevertheless, currently, there are only a few reports about the price fluctuations of chicken eggs, especially about the application of SVM algorithm in the price prediction and assessment. Shen and Wang (2008) made an empirical analysis of the poultry egg consumption in China and their empirical results indicated that there were many factors which could affect the consumption of poultry egg, such as consuming habits, income levels, population scales, urbanization rates and nutrition substitutes and their prices. Li and Li (2009) and Li *et al*. (2010) analyzed the market price of poultry eggs and its short-term price transmission mechanism and forecasting factors. They thought that market factors related to the cost, supply and demand changes could be selected as forecasting factors in the chicken commodity market to make risk warning and further regulation of eggs price varying levels and fluctuations. Tan (2010) analyzed the driving forces of price fluctuations of the food market in China based on the Gonzalo-Granger decomposition and found eggs is one of the long-term crucial affecting factors or driving force of other food price fluctuations. Tang *et al*. (2011) also made an analysis of the livestock product price fluctuation in China based on the ARCH model. Zhu *et al*. (2012) studied the transmission mechanism of price fluctuations in the livestock and poultry product markets of China and reported the price correlations among some products, i.e. pork, chicken and chicken eggs. Liu (2012) and Li *et al*. (2013) looked into the business circumstances operating conditions of fresh egg market in China through the price fluctuation and product cycles analyses. They found the rising feed costs and herds' instability and seasonal price fluctuations caused by the lack of long-term factors in the chicken egg industry chain, such as the price adjusting and risk warning modes to form stable market circumstances and the related industry chain price operating mechanism. Zhou and Li (2012) observed and analyzed the price of chicken eggs since the early years in 21st century using the H-P filtering method. They got the conclusion that the cycle characteristics of chicken egg price variation were rising in long run and varying in a cyclical fluctuation trend in short term. Song (2012) also observed the data of chicken egg price fluctuations in China and the markets of Beijing city from January 2000 to July 2012. Xie *et al*. (2013) analyzed the price transmission mechanism among some chicken eggs main producing and sales areas (i.e. Shandong, Hebei, Henan, Liaoning, Jiangsu, other provinces and Beijing city) in China with the methods of unit root test and impulse response function. They found that the price varying levels and fluctuations in these provinces tended to be consistent or similar with that of Beijing city and there was about a month delay or lag of price transmission time the chicken eggs main producing and sales areas. Zhang *et al*. (2013) reported the empirical research on the effect of chicken egg price fluctuation on the welfare of urban residents with different income levels. They found there was an inverse relationship between the income level of urban residents and the chicken egg price fluctuation. For instance, when the income level was increasing of urban residents, the indicator CR of chicken egg price fluctuation was overall in a process of gradually reducing. Cai and Zhou (2014) analyzed the impacts of endogenous and short-term external influencing factors on the chicken egg price fluctuation in China based on panel data produced during the years 2005-2011. Zhu *et al*. (2015) surveyed the urban decision-making and purchase behavior of chicken eggs and related influencing factors in Beijing city and found that consumers pay more attention to the prices, nutrition and food safety than the brands of chicken eggs. Besides, the consumers' incomes and the supply channels of sales are the important factors affecting the purchase behavior of chicken eggs too. Tan *et al*. (2015) analyzed the characteristics and relevant influence factors of the price fluctuations of chicken eggs in Chinese market. Their results showed that there were obvious seasonal and periodic trends of price fluctuations of chicken eggs and the CPI (Consumer Price Index) and chick's price variations contributed more than those of corn and other feeds to the price fluctuations of chicken eggs. Specially, Deng *et al*. (2009) and Yang *et al*. (2014) tried to detect the eggshell cracks by computer vision method based on the SVM algorithm. Zhu and Ma (2011) also reported the application of computer method in eggs vision and identification based on the SVM model. They identified white fertile and infertile eggs prior to incubation based on computer vision and Least Squares Support Vector Machine (LSSVM). They made 40 samples of infertile eggs and found that the best machine classification accuracy was 92.5%.

Given the market price is the ultimate performance of commodity supply and demand changes in the economic characteristics, such as the retail prices of eggs and chicks, correlations between layers and feed prices vs. input and output in farms, etc., the government and/or administration sector shall establish a price monitoring system in the poultry egg industry chain for risk warning of the egg price fluctuations. However, there are currently few reports of predicting and risk warning of the price fluctuations and relevant variable factors of poultry eggs, especially studies on the price fluctuations of chicken eggs using SVM algorithm. Therefore, it was necessary to model and predict the price fluctuations of chicken eggs based on the theory of SVM algorithm. The aim of this study is to predict and make risk warning of the price fluctuations of chicken eggs in China. The present study is a pilot study to solve the complicated issues of predicting and risk warning of the fluctuations of food prices.

MATERIALS AND METHODS

Data of the price information of chicken eggs: The datasets of the price information of chicken eggs was monthly downloaded and/or retrieved from the websites of China animal husbandry information network and the national bureau of statistics during 2006 and 2012 (Table 1). The monthly recorded datasets were also verified and processed according to the statistics of China Animal Industry Yearbooks 2006-2012. The complex and generally rising trend can be deemed from the price fluctuations of chicken eggs (Table 1). The varying trends of each year are obvious as well as the periodic characteristics of the chicken eggs' price fluctuations as shown in Table 1.

Table 1: Price datasets of chicken eggs and related farm products

Months	Price of chicken egg	Price of pork	Price risk warning index	Price of goods egg chicks	Price of corn	Price of soybean	Price of mixed feed	Consumer satisfaction index
	(Yuan kg^{-1})							
200601	None	None	None	2.01	1.26	2.64	1.87	110.1
200602	5.83	12.18	0.48	1.96	1.27	2.75	1.88	108.0
200603	5.67	11.65	0.49	1.97	1.28	2.69	1.87	107.5
200604	5.54	11.13	0.50	1.89	1.28	2.60	1.86	106.9
200605	5.55	10.71	0.52	1.81	1.34	2.56	1.87	107.1
200606	5.65	10.58	0.53	1.87	1.39	2.54	1.88	107.0
200607	5.72	11.06	0.52	1.84	1.42	2.50	1.89	107.1
200608	6.41	12.01	0.53	2.08	1.43	2.49	1.89	107.6
200609	7.00	12.82	0.55	2.25	1.42	2.50	1.91	108.7
200610	6.99	12.99	0.54	2.24	1.38	2.53	1.91	108.9
200611	6.93	13.35	0.52	2.30	1.40	2.56	1.91	109.4
200612	7.26	14.40	0.50	2.36	1.48	2.63	1.95	110.3
200701	7.31	14.91	0.49	2.37	1.50	2.61	1.97	109.5
200702	7.59	14.97	0.51	2.45	1.51	2.64	1.98	109.0
200703	7.25	14.50	0.50	2.47	1.54	2.73	2.02	109.2
200704	7.25	14.39	0.50	2.54	1.54	2.68	2.01	109.9
200705	7.58	15.86	0.48	2.67	1.55	2.66	2.03	110.6
200706	7.91	17.74	0.45	2.88	1.63	2.67	2.06	112.4
200707	7.59	20.77	0.37	2.83	1.65	2.73	2.09	110.6
200708	8.26	22.95	0.36	3.12	1.66	2.83	2.13	110.9
200709	8.31	22.01	0.38	3.24	1.67	3.15	2.18	110.6
200710	8.14	21.15	0.38	3.11	1.66	3.33	2.19	109.9
200711	7.98	22.35	0.36	2.90	1.69	3.65	2.27	109.4
200712	7.94	24.05	0.33	2.79	1.76	3.83	2.33	110.7
200801	7.92	25.53	0.31	2.61	1.75	3.89	2.41	108.4
200802	7.98	26.08	0.31	2.74	1.77	3.92	2.44	107.6
200803	7.64	25.69	0.30	2.87	1.77	4.06	2.47	107.8
200804	7.52	25.68	0.29	2.95	1.75	4.00	2.47	107.1
200805	7.66	24.71	0.31	2.92	1.75	4.03	2.48	107.2
200806	7.84	24.10	0.33	2.84	1.78	4.31	2.54	107.7
200807	7.80	23.58	0.33	2.65	1.80	4.64	2.91	108.0
200808	8.04	23.18	0.35	2.64	1.79	4.42	2.62	107.2
200809	8.47	22.59	0.37	2.68	1.77	4.32	2.60	107.0
200810	8.15	20.86	0.39	2.61	1.73	4.02	2.55	106.8
200811	7.60	19.46	0.39	2.46	1.66	3.78	2.48	106.1
200812	7.50	20.34	0.37	2.36	1.60	3.61	2.42	103.2
200901	7.56	21.25	0.36	2.33	1.55	3.82	2.40	103.0
200902	7.43	20.62	0.36	2.42	1.54	3.77	2.39	102.6
200903	7.31	19.30	0.38	2.57	1.56	3.54	2.37	102.4
200904	7.44	17.60	0.42	2.62	1.58	3.58	2.37	101.8
200905	7.58	15.68	0.48	2.57	1.60	3.54	2.37	102.4
200906	7.57	15.46	0.49	2.48	1.65	3.65	2.40	102.3
200907	7.42	16.27	0.46	2.40	1.73	3.66	2.44	103.6
200908	7.86	17.94	0.44	2.50	1.79	3.69	2.48	103.8
200909	8.30	18.97	0.44	2.55	1.85	3.72	2.51	103.7
200910	8.04	18.71	0.43	2.48	1.81	3.75	2.52	104.0
200911	7.81	18.47	0.42	2.40	1.82	3.82	2.53	103.8
200912	7.86	19.11	0.41	2.38	1.87	3.90	2.57	103.8
201001	7.79	19.31	0.40	2.35	1.89	3.85	2.58	104.8
201002	8.09	18.67	0.43	2.40	1.90	3.73	2.57	103.7
201003	7.77	17.32	0.45	2.49	1.92	3.61	2.56	107.5
201004	7.57	16.21	0.47	2.47	1.98	3.51	2.58	106.2
201005	7.54	16.09	0.47	2.40	2.03	3.47	2.61	107.7
201006	7.68	16.04	0.48	2.35	2.09	3.35	2.62	107.8
201007	7.99	17.54	0.46	2.43	2.10	3.32	2.62	106.4
201008	8.66	19.30	0.45	2.62	2.11	3.45	2.63	106.2
201009	9.23	20.11	0.46	2.74	2.11	3.50	2.64	103.4
201010	9.05	20.42	0.44	2.71	2.07	3.64	2.65	103.1
201011	9.43	21.33	0.44	2.76	2.10	3.75	2.68	102.5

Table 1: Continue

Months	Price of chicken egg	Price of pork	Price risk warning index	Price of goods egg chicks	Price of corn	Price of soybean	Price of mixed feed	Consumer satisfaction index
	(Yuan kg^{-1})							
201012	9.63	21.94	0.44	2.82	2.12	3.69	2.70	100.1
201101	9.87	22.17	0.45	2.81	2.11	3.68	2.70	99.8
201102	10.07	22.97	0.44	2.89	2.13	3.71	2.71	99.5
201103	9.38	23.09	0.41	3.00	2.16	3.66	2.74	104.8
201104	9.20	23.39	0.39	3.05	2.19	3.59	2.75	105.1
201105	9.51	23.97	0.40	3.11	2.22	3.53	2.76	104.6
201106	10.07	26.71	0.38	3.22	2.28	3.53	2.79	103.2
201107	10.18	29.31	0.35	3.33	2.35	3.57	2.83	96.2
201108	10.64	29.82	0.36	3.43	2.39	3.60	2.87	97.9
201109	11.03	30.35	0.36	3.53	2.45	3.62	2.91	95.2
201110	10.66	29.78	0.36	3.49	2.45	3.57	2.91	91.8
201111	10.16	27.94	0.36	3.41	2.39	3.51	2.90	90.0
201112	9.88	27.17	0.36	3.33	2.36	3.42	2.88	93.2
201201	9.84	27.83	0.35	3.27	2.35	3.43	2.88	95.8
201202	9.18	27.36	0.34	3.19	2.35	3.46	2.88	96.1
201203	8.62	25.79	0.33	3.15	2.37	3.51	2.90	90.2
201204	8.41	24.36	0.35	3.15	2.42	3.63	2.93	94.7
201205	8.23	23.31	0.35	3.07	2.46	3.69	2.95	97.1
201206	9.29	22.78	0.41	None	None	None	None	None

Data used in the price risk warning prediction of chicken eggs

Definition of the risk alert index of chicken egg price fluctuations: As the most common edible foods, pork has the function properties similar to eggs and its sale price is often used as a barometer of agricultural products market stability by the government and scholars. Therefore, pork is suitable as the reference in the price fluctuations of chicken eggs. The price fluctuation risk alert index of chicken eggs for analysis is defined with the coefficient method as follows:

$$R = \frac{P_i}{P_j} \quad (1)$$

where, R represents the risk alert index, while P_i is marked as the chicken egg price and P_j is the pork prices.

Risk warning sources and warning factors determined for chicken egg price fluctuations: The risk warning sources is usually referred as the root causes of risk which decides the price levels and the influencing factors of the price fluctuations of chicken egg. The price fluctuation of chicken egg is the result of comprehensive shaping by many factors in the market. It is more complex than one can imagine. Therefore, the risk warning sources should involve all the natural, social, economic and political factors besides the market and other aspects (Table 2). On the other hand, the risk warning sources and the influencing factors of the chicken egg pricing should reflect the market changes, i.e. the variation of supply and demand and cost. So, the risk warning analysis of price fluctuation of chicken eggs can be started from the main aspects of market, such as cost, supply and demand and relevant factors. Through analysis of the main aspects of market and relevant factors for chicken egg pricing, a number of information prices were finally chosen as the risk warning indexes or indicators of chicken egg prices, i.e. the price of egg type chicks, the price of corn, the price of soybean meal, the price of laying hens feed, customer satisfaction index and other indicators. Then, the egg price risk warning limits and warning

Table 2: Risk warning degree and limit of chicken egg prices

Risk warning degree	Risk warning limit	Risk warning index	Label	Meaning (significance)
Negative high risk warning	$(-\infty, m-2\sigma)$	$(-\infty, 0.28)$	-2	Egg price is too low
Negative light risk warning	$(m-2\sigma, m-\sigma)$	(0.28, 0.35)	-1	Egg price is on the low side
There is no risk warning	$(m-\sigma, m+\sigma)$	(0.35, 0.49)	0	Egg price is relatively reasonable
Positive light risk warning	$(m+\sigma, m+2\sigma)$	(0.49, 0.56)	+1	Egg price is on the high side
Positive high risk warning	$(m+2\sigma, +\infty)$	$(0.56, +\infty)$	+2	Egg price is too high

degrees were determined adopting the combination of different types of risk warning indexes using the Libsvm software package (Chang and Lin, 2011) to establish the price risk warning model based on the SVM algorithm.

Price risk warning limits and degrees determined for chicken egg price fluctuations: The original data of the prices was downloaded from China animal husbandry information network website and the national bureau of statistics website during 2006 and 2012 (Table 1), including the prices of chicken eggs, pork, egg type chicks, corn and soybean meal, laying hens feeds and other relevant data, such as customer satisfaction index. In the risk warning model, this study used the price risk warning information of a former monthly indexes to predict the risk warning indexes of next month with data selected between January 2006 and May 2012. Among the monthly indexes, the pricing data collected from February 2012 to June 2012 was taken as the training set of sample data (input data) to make the prediction and comparison of the pricing data from June 2012 to November 2012 (output data; testing set or predicting set), with the possible price risk warning indexes.

Determination of the risk warning limits and degrees of chicken egg prices: The risk warning limit refers to the degree and interval of change or damage, while the risk warning degree is the description of change or damage. These two indexes are determined based on all the market data available limited to pricing. Based on the training set of sample data, the risk warning index was regarded as the reference point, while an average of the standard deviation was taken as a threshold limit of the risk warning. Then, any point deviating from the benchmark within one standard deviation was in the interval of no guard, while the point deviating between one standard deviation and two standard deviations was in the interval of light risk warning and the point being more than two standard deviating was in the interval of high or heavy risk warning (Table 2).

It should be noted that a major precinct was separated by the positive and negative intervals. Therefore, the whole precincts of price risk warning degree and alarm limit of chicken eggs was divided into five grades according to the positive and negative precincts (Table 2). Therefore, the risk warning index of training set of sample data previously acquired was calculated as 0.42 and the average of the standard deviation was deduced as 0.07 accordingly.

Theory and models of Support Vector Machine (SVM) algorithm: The SVM algorithm is a kind of statistical learning theory based on machine learning methods. Since, the SVM algorithm can solve many issues, such as small samples and nonlinear and local minimum points, it is widely used in the statistical classification and regression analysis. Herein, the SVM algorithm is introduced and used to predict and model the risk warning indexes of chicken egg prices with the input training sample dataset (Table 3).

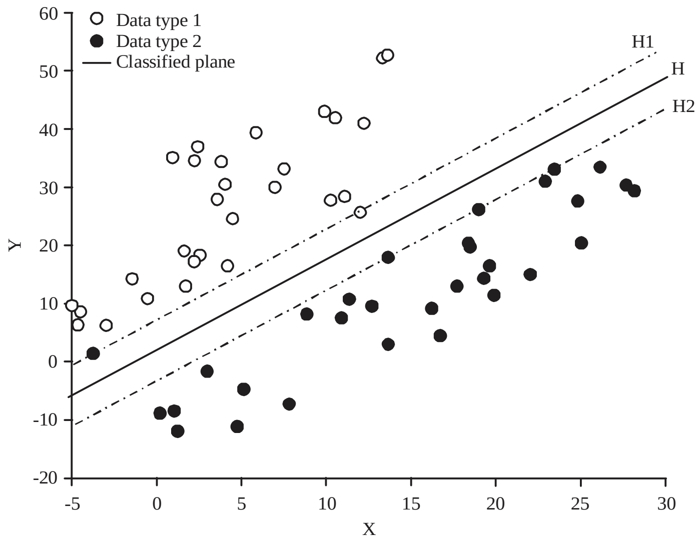

Fig. 1: Classification plane of support vector machine

Table 3: Price input training sample dataset in support vector machine models

Months	Prices of goods egg chicks	Prices of corn	Prices of soybean	Prices of mixed feed	Consumer satisfaction index
	--------(Yuan kg^{-1})--------				
201206	3.10	2.49	3.68	2.96	93.3
201207	3.07	2.51	3.83	2.99	93.3
201208	3.11	2.55	4.20	3.05	93.0
201209	3.19	2.57	4.52	3.10	96.0
201210	3.14	2.51	4.39	3.09	101.2
201211	3.12	2.34	4.17	3.06	98.6

Linearly separable Support Vector Machine (SVM): Assuming that there is a sample set (Xi, Xj), (I = 1, 2, 3, n), Xi∈Rn, where n is the total number of samples, Xi belong to two kinds of one kind, with Yi∈ {1, 1} to tag. In the case of the linear separable variables in Support Vector Machine (SVM), the sample set was separated by straight lines, as shown in Fig. 1. In the figure, the points in a square and/or a circular are two kinds of sample points respectively. The line H is the right classification line of the separated two types of sample points, while H1 and H2 are the parallel classification interval lines of these sample points closest to the straight classification line H. The distance between H1 and H2 is called the sample classification interval or margin of the two classes sample points. The optimal classification lines can not only separate the two kinds of sample points but also make the largest classification interval of the sample points. Then, the optimal classification lines will become the optimal classification plane or the classification hyperplane to obtain a high dimension space.

Remember the classification hyperplane as follows:

$$H = \{x \mid w \bullet x)+b = 0\} \tag{2}$$

In the formula, the marker "•" represents the vector product, x is a vector of sample points, w is the normal vector of classification hyperplane and b is set as the distance between the classification hyperplane relative to the origin point or initial place in the coordinate diagram.

In the classification hyperplane, the training sample dataset is divided into the following two categories:

$$(w \bullet x_i)+b>0 \Rightarrow y_i = +1 = 0\} \quad (3)$$

$$(w \bullet x_i)+b<0 \Rightarrow y_i = -1 = 0\} \quad (4)$$

where, the non-negative classification interval can be expressed as the function, $y_i\,(w \bullet x_i)+b$ which is equivalent to the value of the following variable $|(w \bullet x_i)+b|$. Let us suppose the undetermined coefficients (w, b) are replaced by the standardized datasets $((w/\|w\|, b/\|b\|)$ or normalization processed values and then the classification interval is equal to $2/\|w\|$. The original problem of margin maximization becomes the issue of the minimized variable $\|w\|$. Therefore, the optimization of classification hyperplane can be transformed into the following minimized variable issue with optimal constraints and standard deviation:

$$\frac{1}{2}\|w\|^2 \quad (5)$$

Standard deviation:

$$y_i\,(w \bullet x_i)+b \geq 1,\ i = 1, 2, 3,..., n \quad (6)$$

To resolve the optimization problem with constraints, one can establish a Lagrange function by introducing the following Lagrange multiplier:

$$\alpha_i \geq 0,\ i = 1, 2, 3,..., n$$

Thus, one can get the Lagrange function:

$$L(w,b,\alpha) = \frac{1}{2}\|w\|^2 - \sum_{i=1}^{n}\alpha_i[y_i(w \bullet x_i + b) - 1] \quad (7)$$

Assuming that the following formulas hold:

$$\frac{\partial L}{\partial w} = 0 \Rightarrow w = \sum_{i=1}^{n}\alpha_i y_i x_i \quad (8)$$

$$\frac{\partial L}{\partial b} = 0 \Rightarrow \sum_{i=1}^{n}\alpha_i y_i = 0 \quad (9)$$

$$\frac{\partial L}{\partial \alpha_i} = 0 \Rightarrow \alpha_i[y_i(w \bullet x_i + b) - 1] = 0 \quad (10)$$

Then, the original problem is transformed into a dual issue as follows:
Maximization:

$$\sum_{i=1}^{n}\alpha_i - \frac{1}{2}\sum_{i=1}^{n}\alpha_i y_i \sum_{j=1}^{n}\alpha_j y_j (x_i \bullet x_j) = \sum_{i=1}^{n}\alpha_i - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_i\alpha_j y_i y_j (x_i \bullet x_j) \quad (11)$$

Standard deviation:

$$\sum_{i=1}^{n} \alpha_i y_i = 0 \tag{12}$$

where, $\alpha_i \geq 0$, i = 1, 2, 3,..., n.

Assuming that $\alpha^* = (\alpha_1^*, \alpha_2^*, \alpha_3^*, ...\alpha_n^*)^T$ is the right solution of the original optimization problem with the constraint $(\alpha^* \neq 0)^T$, the following calculation can be available:

$$w^* = \sum_{i=1}^{n} \alpha_1^* y_i x_i \tag{13}$$

$$b^* = y_j - \sum_{i=1}^{n} \alpha_i^* y_i (x_i \bullet x_j) \tag{14}$$

To construct an optimal classification hyperplane again as follows:

$$w^* \bullet x + b^* = 0 \tag{15}$$

The following decision function is to be obtained:

$$f(x) = \mathrm{sgn}(w^* \bullet x + b^*) = \mathrm{sgn}[\sum_{i=1}^{n} y_i \alpha_i^* (x_i \bullet x) + b^*] \tag{16}$$

For concrete calculation and operation, the input sample can be classified into the generations of different types, including the corresponding Vectors X_i which is so-called Support Vector (SV). Otherwise, the included vectors X_i is called Non Support Vector (NSV) and the corresponding input sample is named the non support vector sample.

Linear inseparable Support Vector Machine (SVM): For linearly in separable problem, the optimization requirements of the optimized classification hyperplane must be reduced to the minimum which does not meet the constraints since there may not exist such a classification hyperplane. Assuming that there are the following training points with the constraints:

$$y_i (w \bullet x_i) + b \geq 1, \ i = 1, 2, 3, ..., n \tag{17}$$

By introducing a slack variable ($\varepsilon_i \geq 0$, i = 1, 2, 3,..., n), the constraint conditions of optimization can be reduced to the following requirement:

$$y_i (w \bullet x_i) + b \geq 1 - \varepsilon_i, \ i = 1, 2, 3, ..., n \tag{18}$$

Obviously, when the slack variable, ε_i (i = 1, 2, 3,..., n) becomes sufficiently large, there are always some training sample points to be satisfying the following constraints:

$(x_i \bullet y_i)$, i = 1, 2, 3,..., n

However, it's meaningless to take too much of a value of the slack variable. One can add an additional variable containing the punishment scores to the objective function:

$$\left(\sum_{i=1}^{n} \varepsilon_i\right)$$

for calculation. Therefore, the SVM algorithm can be realized by solving the following issues:

Minimization:

$$\frac{1}{2}\|w\|^2 + C\sum_{i=1}^{n} \varepsilon_i \quad (19)$$

Standard deviation:

$$y_i\,(w \bullet x_i) + b \geq 1 - \varepsilon_i,\ i = 1, 2, 3, \ldots, n \quad (20)$$

$$\varepsilon_i \geq 0,\ i = 1, 2, 3, \ldots, n \quad (21)$$

where, C (C>0) is a penalty parameter which reflects the degree of the trade-offs between the minimized and maximized intervals of classification hyperplane.

Introducing the Lagrange function again, the dual problem can be obtained.

Maximization:

$$\sum_{j=1}^{n} \alpha_i - \frac{1}{2}\sum_{i=1}^{n} \alpha_i y_i \sum_{j=1}^{n} \alpha_j y_j (x_i \bullet x_j) = \sum_{j=1}^{n} \alpha_i - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \alpha_i \alpha_j y_i y_j (x_i \bullet x_j) \quad (22)$$

Standard deviation:

$$\sum_{i=1}^{n} \alpha_i y_i = 0 \quad (23)$$

$$C - \alpha_i - \beta_i = 0,\ i = 1, 2, 3, \ldots, n \quad (24)$$

$$\alpha_i \geq 0,\ i = 1, 2, 3, \ldots, n \quad (25)$$

$$\beta_i \geq 0,\ i = 1, 2, 3, \ldots, n \quad (26)$$

The following parameters can be calculated and predicted:

$$w^* = \sum_{i=1}^{n} \alpha_1^* y_i x_i \quad (27)$$

$$b^* = y_j - \sum_{i=1}^{n} \alpha_1^* y_i (x_i \bullet x_j) \tag{28}$$

Constructing a classification hyperplane as follows:

$$w^* \bullet x + b^* = 0 \tag{29}$$

Then, the following decision function will finally be obtained:

$$f(x) = \text{sgn}(w^* \bullet x + b^*) = \text{sgn}[\sum_{i=1}^{n} y_i \alpha_i^* (x_i \bullet x) + b^*] \tag{30}$$

Nonlinear Support Vector Machine (NSVM): Based on the Linear Support Vector Machine (LSVM), nonlinear Support Vector Machine (NSVM) can also be realized by adding a kernel function, such as the following:

$$K\ (x_i, x_j),\ i = 1, 2, 3, \ldots, n \tag{31}$$

Therefore, the transformation of nonlinear to linear classifications can be realized without increasing the computational complexity in the optimal classification plane by choosing appropriate kernel functions.

The optimization problem of nonlinear classification can be transformed into the following:

Maximization:

$$\sum_{j=1}^{n} \alpha_i - \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_i \alpha_j y_i y_j K(x_i \bullet x_j) \tag{32}$$

Standard deviation:

$$\sum_{i=1}^{n} \alpha_i y_i = 0 \tag{33}$$

$$C\text{-}\alpha_i\text{-}\beta_i = 0,\ i = 1, 2, 3, \ldots, n \tag{34}$$

$$\alpha_i \geq 0,\ i = 1, 2, 3, \ldots, n \tag{35}$$

$$\beta_i \geq 0,\ i = 1, 2, 3, \ldots, n \tag{36}$$

The corresponding classification function will be transformed to the following format:

$$f(x) = \text{sgn}[\sum_{i=1}^{n} y_i \alpha_i^* K(x_i \bullet x) + b^*] \tag{37}$$

At present, there are four kinds of commonly used kernel functions for NSVM, respectively.

Radial basis kernel function:

$$k(x_i, x_j) = \exp(-\gamma\|x_i - x_j\|^2), \gamma>0, i = 1, 2, 3,..., n \quad (38)$$

Sigmoid kernel function:

$$K(x_i, x_j) = \tanh(\gamma \bullet x_i^T x_j + r), i = 1, 2, 3,..., n \quad (39)$$

RESULTS AND DISCUSSION

Correlation analysis between the risk warning indexes and related influencing factors of chicken egg prices: Through the root causes and correlation analyses of the price risk warning of chicken egg, together with the statistical data available, there were seven preliminary causing factors and/or major influencing factors related to cost, supply and demand in the pricing and decision-making models to be considered with according to references (Wu, 2009; Li and Li, 2009; Li *et al*., 2010, 2013; Xie *et al*., 2013; Zhang *et al*., 2013; Cai and Zhou, 2014; Tan *et al*., 2015), such as the price of egg type chicks, the price of corn, the price of soybean, the price of mixed feed prices for laying hens, consumer expectations index, customer satisfaction index and consumer confidence index, etc. Through the correlation analysis of these influencing factors, there were significant correlations found between the price risk warning index (R) and five price influencing factors (Wu, 2009; Li *et al*., 2010; Xie *et al*., 2013; Cai and Zhou, 2014; Tan *et al*., 2015), i.e. the price of egg type chicks, the price of corn, the price of soybean, the price of mixed feed prices for laying hens and customer satisfaction index. Other minor influencing factors were finally eliminated (Table 4).

Prediction model and risk assessment of the price fluctuations of chicken eggs based on Support Vector Machine (NSVM): algorithm: Data classification issues in any SVM models usually include the training and the testing datasets. Each training set data has a target, named the category labels and the attribute values (i.e. the variables). The SVM algorithm and models used here was to classify and predict all the target values of test datasets with the attribute parameters based on the training dataset and the testing models. Meanwhile, those five price influencing factors and their corresponding indexes could be divided into three groups or categories in the study, i.e. the chicken cost group including the prices of egg type chicks regarded as the cost of laying hens, the feed cost group including the prices of corn, soybean and mixed feed and the demand group including the customer satisfaction index and related factors.

In order to observe the effects of different combinations of price risk warning indexes and influencing factors in detail, there were totally six SVM models used for the prediction and risk assessment of price fluctuations of chicken eggs in the famous Libsvm software package (Chang and Lin, 2011). These SVM models used in the study are developed as the following.

Table 4: Correlation analysis of main price risk warning influencing factors

Statistics	Prices of goods egg chicks	Prices of corn	Prices of soybean	Prices of mixed feed	Consumer expectations index	Consumer satisfaction index	Consumer confidence index
	-------------------------(Yuan kg^{-1})			------------------------			
Pearson correlation coefficient	-0.645	-0.418	-0.65	-0.541	0.034	0.308	0.174
Statistical significance (double sided inspection)	0.000	0.000	0.000	0.000	0.756	0.004	0.113

Model 1: The risk warning index was designed using the chicken cost, i.e. the price of egg type chicks. Model 2: The risk warning index was designed using the feed cost, i.e. the prices of corn, soybean and mixed feed. Model 3: The risk warning index was designed using the indicator of demand factors, i.e. the customer satisfaction index. Model 4: The risk warning index was designed using the combination of chicken and feed costs, i.e. the prices of egg type chicks, corn, soybean and mixed feed. Model 5: The risk warning index was designed using the combination of feed cost and the demand factor, i.e. the prices of corn, soybean, mixed feed and the customer satisfaction index. Model 6: The risk warning index was designed using the combination of chicken and feed costs and indicator of demand factors, i.e. all the five influencing factors and their indicators.

Selection of radial basis kernel function and sigmoid kernel function: Due to the complexity of egg price risk warning model, it is suggested to choose proper kernel functions and make the models of NSVM applicable in dataset modeling. In this study, both the radial basis kernel function and sigmoid kernel function could be selected for the NSVM models established. However, the radial basis kernel function is generally preferred. In general, the radial basis kernel function is corresponding with the infinite dimensional space and the characteristics of most limited sample datasets are linearly separable in the featured space. Therefore, this kernel function can solve the non-linear relations between the type of tags and attributes. Thus, the following radial basis kernel function was preferred to establish the price risk warning models of chicken eggs.

$$K(x_i, x_j) = \exp(-\gamma \|x_i - x_j\|^2), \gamma > 0, i = 1, 2, 3, \ldots, n \quad (40)$$

In the above SVM models using Radial basis kernel function and two key parameters (C, g) should be optimized by the cross validation and grid search methods. These operations were all realized in the Libsvm software package (Chang and Lin, 2011) with the following united typed input program command "C:\libsvm-3.14\windows>python grid.py train.txt". Through multiple tests, the derived optimized parameters (C, g), simulation accuracies and output files for models 1-6 were shown in Table 4-5. Then, the final optimized SVM models were obtained with the following united typed training and output program commands, i.e. "C:\libsvm-3.14\windows>svm-train -c -g train.txt" and "C:\libsvm-3.14\windows>svm-predict test.txt train1.txt.model test.txt.out". Thus, we obtained the optimized models 1-6 and their output files for the prediction and assessment of chicken egg prices with risk warning using the standardized datasets (input training datasets) retrieved from the Chinese official websites during July 2012 and December 2012 (Table 5). Furthermore, the optimal parameters, indexes and predicted results of the chicken eggs' egg price risk warning using the SVM models were shown in Table 6-8.

Predicted price values, risk warning indexes and predicting accuracies of chicken egg prices by the Support Vector Machine (SVM) models: Table 6 showed the final optimized parameters (i.e. C, g) of the SVM algorithm in different predicting models of chicken egg prices in China. Using these optimal parameters and input datasets collected during the months from 200601-201206 in China (Table 5), the actual price values and the risk warning limit and degree indexes of later six months' chicken egg prices were revealed in Table 7 and 8. In Table 7, it was found that the actual values of price risk warning limit indexes varied from 0.40-0.45 and the actual values of price risk warning degree indexes were kept as 0, which meant that the chicken

Table 5: Standardized output datasets of predicted chicken egg prices in support vector machine models

Months	Dealt prices of goods egg chicks	Dealt prices of corn	Dealt prices of soybean	Dealt prices of mixed feed	Dealt consumer satisfaction index
	----(Yuan kg^{-1})----				
200601	-0.77	-1.00	-0.86	-0.98	0.79
200602	-0.83	-0.98	-0.76	-0.96	0.60
200603	-0.81	-0.97	-0.81	-0.98	0.56
200604	-0.91	-0.97	-0.90	-1.00	0.51
200605	-1.00	-0.87	-0.93	-0.98	0.53
200606	-0.93	-0.78	-0.95	-0.96	0.52
200607	-0.97	-0.73	-0.99	-0.94	0.53
200608	-0.69	-0.72	-1.00	-0.94	0.57
200609	-0.49	-0.73	-0.99	-0.91	0.67
200610	-0.50	-0.80	-0.96	-0.91	0.69
200611	-0.43	-0.77	-0.93	-0.91	0.73
200612	-0.36	-0.63	-0.87	-0.83	0.82
200701	-0.35	-0.60	-0.89	-0.80	0.74
200702	-0.26	-0.58	-0.86	-0.78	0.70
200703	-0.23	-0.53	-0.78	-0.71	0.71
200704	-0.15	-0.53	-0.82	-0.72	0.77
200705	0.00	-0.52	-0.84	-0.69	0.84
200706	0.24	-0.38	-0.83	-0.63	1.00
200707	0.19	-0.35	-0.78	-0.58	0.84
200708	0.52	-0.33	-0.68	-0.50	0.87
200709	0.66	-0.32	-0.39	-0.41	0.84
200710	0.51	-0.33	-0.22	-0.39	0.77
200711	0.27	-0.28	0.08	-0.25	0.73
200712	0.14	-0.17	0.25	-0.14	0.85
200801	-0.07	-0.18	0.30	0.01	0.65
200802	0.08	-0.15	0.33	0.06	0.57
200803	0.23	-0.15	0.46	0.12	0.59
200804	0.33	-0.18	0.40	0.12	0.53
200805	0.29	-0.18	0.43	0.14	0.54
200806	0.20	-0.13	0.69	0.25	0.58
200807	-0.02	-0.10	1.00	0.93	0.60
200808	-0.03	-0.12	0.80	0.39	0.54
200809	0.01	-0.15	0.70	0.36	0.52
200810	-0.07	-0.22	0.42	0.27	0.50
200811	-0.24	-0.33	0.20	0.14	0.43
200812	-0.36	-0.43	0.04	0.03	0.18
200901	-0.40	-0.52	0.24	-0.01	0.16
200902	-0.29	-0.53	0.19	-0.03	0.12
200903	-0.12	-0.50	-0.02	-0.06	0.11
200904	-0.06	-0.47	0.01	-0.06	0.05
200905	-0.12	-0.43	-0.02	-0.06	0.11
200906	-0.22	-0.35	0.08	-0.01	0.10
200907	-0.31	-0.22	0.09	0.06	0.21
200908	-0.20	-0.12	0.12	0.14	0.23
200909	-0.14	-0.02	0.14	0.19	0.22
200910	-0.22	-0.08	0.17	0.21	0.25
200911	-0.31	-0.07	0.24	0.23	0.23
200912	-0.34	0.02	0.31	0.30	0.23
201001	-0.37	0.05	0.27	0.32	0.32
201002	-0.31	0.07	0.15	0.30	0.22
201003	-0.21	0.10	0.04	0.28	0.56
201004	-0.23	0.20	-0.05	0.32	0.45
201005	-0.31	0.28	-0.09	0.38	0.58
201006	-0.37	0.38	-0.2	0.39	0.59
201007	-0.28	0.40	-0.23	0.39	0.46
201008	-0.06	0.42	-0.11	0.41	0.45
201009	0.08	0.42	-0.06	0.43	0.20
201010	0.05	0.35	0.07	0.45	0.17
201011	0.10	0.40	0.17	0.50	0.12

Table 5: Continue

Months	Dealt prices of goods egg chicks (Yuan kg^{-1})	Dealt prices of corn (Yuan kg^{-1})	Dealt prices of soybean (Yuan kg^{-1})	Dealt prices of mixed feed (Yuan kg^{-1})	Dealt consumer satisfaction index
201012	0.17	0.43	0.12	0.54	-0.10
201101	0.16	0.42	0.11	0.54	-0.13
201102	0.26	0.45	0.13	0.56	-0.15
201103	0.38	0.50	0.09	0.61	0.32
201104	0.44	0.55	0.02	0.63	0.35
201105	0.51	0.60	-0.03	0.65	0.30
201106	0.64	0.70	-0.03	0.71	0.18
201107	0.77	0.82	0.00	0.78	-0.45
201108	0.88	0.88	0.03	0.85	-0.29
201109	1.00	0.98	0.05	0.93	-0.54
201110	0.95	0.98	0.00	0.93	-0.84
201111	0.86	0.88	-0.05	0.91	-1.00
201112	0.77	0.83	-0.13	0.87	-0.71
201201	0.70	0.82	-0.13	0.87	-0.48
201202	0.60	0.82	-0.10	0.87	-0.46
201203	0.56	0.85	-0.05	0.91	-0.98
201204	0.56	0.93	0.06	0.96	-0.58
201205	0.47	1.00	0.12	1.00	-0.37
201206	0.50	1.05	0.11	1.02	-0.71
201207	0.47	1.08	0.25	1.07	-0.71
201208	0.51	1.15	0.59	1.18	-0.73
201209	0.60	1.18	0.89	1.28	-0.46
201210	0.55	1.08	0.77	1.26	0.00
201211	0.52	0.80	0.56	1.20	-0.23
201212	0.45	0.76	0.49	1.16	-0.20

Table 6: Optimal parameters in the support vector machine different predicting models of chicken egg prices

Parameters	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
C	32	32	8	8	48	8
g	8.0	2.0	8.0	2.0	0.5	2.0

Table 7: Actual values of the risk warning indexes of chicken egg prices

Months	Prices of chicken egg risk warning degree (Yuan kg^{-1})	Prices of pork (Yuan kg^{-1})	Actual values of price risk warning limit	Actual values of price risk warning degree
201207	9.09	22.61	0.40	0
201208	9.70	22.94	0.42	0
201209	10.60	23.80	0.45	0
201210	10.35	23.92	0.43	0
201211	10.17	23.76	0.43	0
201212	10.54	24.82	0.42	0

Table 8: Predicted price risk warning degrees and predicting accuracies of the chicken egg prices by different support vector machine models

Months	Predicted values of price risk warning degree in model 1	Predicted values of price risk warning degree in model 2	Predicted values of price risk warning degree in model 3	Predicted values of price risk warning degree in model 4	Predicted values of price risk warning degree in model 5	Predicted values of price risk warning degree in model 6
201207	0	0	-1	0	0	-1
201208	0	0	-1	0	0	0
201209	0	0	-1	0	0	0
201210	-1	0	0	0	0	0
201211	0	0	0	0	0	0
201212	0	-1	0	0	0	0
Accuracy	83.33%	83.33%	50%	100%	100%	83.33%

egg prices were relatively steady during the months from 200601-201206 in China (Table 7). Table 8 showed the specific predicted price risk warning degrees and predicting accuracies of the chicken egg prices by different SVM models in details. It was seen that the predicted accuracies of five models were proved to be more than 80% and only that of model 3 was 50% by comparison with the actual risk warning values of chicken egg price fluctuations. Particularly, the predicted accuracies of models 4 and 5 were 100%.

In brief, it was found that the predicting accuracies of models 1, 2, 4, 5 and 6 were relatively higher than that of model 3 among the predicted results of price risk warning in the SVM simulating models (Table 6-7). Especially, the predicting accuracies of former five models were all over 80% and those of models 4 and 5 even reached 100%, while that of model 3 was only 50%. In general, the costs of feeding and farming of layer chickens mainly include the goods egg chick cost, feed cost, labor wages, the disease prevention and cure fees and the charges of the fuel, electricity, water, equipment and fixed assets depreciation cost housing in the farm (Wu, 2009; Li and Li, 2009; Li *et al*., 2010, 2013; Xie *et al*., 2013; Zhang *et al*., 2013; Cai and Zhou, 2014; Tan *et al*., 2015), in addition to the needed fees for sales, marketing and advertising, etc. Among the costs of chicken egg production, the largest part was spent on feeding (about 60-70% of the total) and the second part was frequently on the cost of goods egg chicks and breeding (about 15-20% of the total) (Wu, 2009; Li *et al*., 2010; Xie *et al*., 2013; Cai and Zhou, 2014; Tan *et al*., 2015). It was proved to be true in the study too. Moreover, the next charges were the fees for disease prevention and cure, sales, marketing and advertising, etc (Wu, 2009; Tan *et al*., 2015). Furthermore, the feed cost was the main influencing factor and/or indicator of the whole egg producing cost determining the prices of chicken eggs in farms (Wu, 2009; Tan *et al*., 2015). From the simulated results of the SVM models (Table 5-8), it was also inferred that the customer satisfaction index was relatively insignificant, while the cost and demand influencing factors and indexes were significant for predicting the price fluctuations of chicken eggs. For instance, among all the chick and chicken feeds, corn and soybean were the usual raw materials, energy and protein components in chicken feeds or meals that account for 60-65 and 20-25% of the layer's nutrients, respectively (Wu, 2009; Li *et al*., 2010; Xie *et al*., 2013; Tan *et al*., 2015). Meanwhile, the mixed feed was important and common to the adult layer chickens. The price changes of the costs of corn and soybean, mixed feed and other feed raw materials, will directly affect the changes of chicken feed costs and thus affect the price fluctuations of chicken eggs. On the other hand, the goods egg chick cost has a potential long-term impact on the price fluctuations of chicken eggs (Wu, 2009; Li *et al*., 2010; Xie *et al*., 2013; Tan *et al*., 2015). In fact, the disease of disease prevention and control will affect the survival rates of chicks and the goods egg chick cost via the biological mechanism of microbiology, e.g. avian *Salmonella*, *Escherichia coli* and the polluting of chicken Marek's Disease Virus (MDV). Therefore, the charge for disease control and prevention was integrated into the goods egg chick cost regarding the availability and complexity of the sample data of the study. On the other hand, the charged fees and economic benefit for sales, marketing and advertising of chicken eggs can be indicated by the customer satisfaction indexes (Wu, 2009; Li *et al*., 2010; Xie *et al*., 2013; Cai and Zhou, 2014; Tan *et al*., 2015). However, the influence of customer satisfaction indexes was tiny as shown by both the correlation analysis and the modeling results of chicken egg prices and relevant risk warning indexes using SVM algorithm in the study (Table 6-8). In short, among these SVM models, the low accuracy of model 3 revealed that the customer satisfaction index was relatively unimportant or insignificant, while the high accuracies of other models indicated the cost and demand influencing factors and indexes were significant for predicting the price fluctuations of chicken eggs. The cost and demand influencing factors and related indexes should be considered in the future studies.

CONCLUSION

The present study was designed to predict and assess the chicken egg prices and corresponding fluctuations in China with risk warning using SVM algorithm from the aspects of cost, supply and demand. Firstly, through correlation analysis, five main influencing factors (i.e. the prices of egg type chicks, corn, soybean and mixed feed and the consumer satisfaction index) were chosen in the prediction and assessment of chicken egg price fluctuations. These five indexes were divided into three categories, i.e. the chicken cost, the feed cost and the demand influencing factors and the risk warning limits and degrees of chicken egg price fluctuations were determined according to reference points of average values and intervals produced from the sample data previously acquired. Next, six SVM models of different combinations of the price risk warning indexes were established and used to train and test the datasets with the corresponding optimized parameters. The predicted accuracies of five models were proved to be more than 80% and only that of model 3 was 50% by comparison with the actual risk warning values of chicken egg price fluctuations. Specifically, the predicted accuracies of models 4 and 5 were 100%. The actual price values and the risk warning limit and degree indexes of later six months' chicken egg prices from 200601-201206 in China were revealed too. It was finally inferred that the six months' chicken egg prices were relatively steady. From the simulated results of these SVM models, it was also inferred that the customer satisfaction index was relatively insignificant, while the cost and demand influencing factors and indexes were significant for predicting the price fluctuations of chicken eggs. The SVM models used in the present study can be further used to model and predict the price fluctuations of other commercial food products too.

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REFERENCES

Bak, P., K. Chen, J. Scheinkman and M. Woodford, 1993. Aggregate fluctuations from independent sectoral shocks: Self-organized criticality in a model of production and inventory dynamics. Ricerche Economiche, 47: 3-30.

Cai, S.J. and Y.H. Zhou, 2014. Endogenous and short-term external impact on egg price fluctuation in China: Based on panel date of 31 provinces (cities or prefectures) from 2005 to 2011. J. Hunan Agric. Univ., 15: 21-26.

Chang, C.C. and C.J. Lin, 2011. LIBSVM: A library for support vector machines. ACM Trans. Intell. Syst. Technol., 2: 1-39.

Deng, X., Q. Wang, L. Wu, H. Gao, Y. Wen and S. Wang, 2009. Eggshell crack detection by acoustic impulse response and support vector machine. Afr. J. Agric. Res., 4: 40-48.

Li, G., S. Xu, Z. Li, X. Dong and S. Wang, 2013. Study on law of fresh agricultural products market price fluctuation: Cycle analysis based on H-P model. Agric. Outlook, 1: 30-34.

Li, Z.M. and G.Q. Li, 2009. Analyses of the market price of poultry eggs and its short-term forecasting factors. Food Nutr. China, 12: 36-39, (In Chinese).

Li, Z.M., S.W. Xu, X.X. Dong, G.Q. Li, H. Liu and Y.T. Wang, 2010. The short-term market price transmission mechanism of egg industry chain in China. Scientia Agricultura Sinica, 43: 4951-4962, (In Chinese).

Liu, Z.B., 2012. [Analysis of the price fluctuations in Chinese fresh egg market in recent years]. Chinese J. Anim. Sci., 2: 63-66, (In Chinese).

Shen, Q. and J. Wang, 2008. The influence factors and empirical analysis of the poultry egg consumption level in China. Food Nutr. China, 4: 33-36, (In Chinese).

Song, S., 2012. Analysis of the price fluctuation law and relevant causing reasons of chicken eggs. Agric. Outlook, 9: 21-23, (In Chinese).

Tan, B., 2010. Analysis of the driving forces of food price fluctuations in China based on the Gonzalo-Granger decomposition. Prices Monthly, 11: 1-6, (In Chinese).

Tan, Q.H., Z. Wang and Y.F. Chen, 2015. Analysis of the characteristics and influence factors of the price fluctuations of chicken eggs in China. Anim. Husbandry Vet. Med., 47: 125-129, (In Chinese).

Tang, J., N. Lei and X. Xu, 2011. Analysis on price fluctuation of livestock product in China: Based on ARCH-type model. Technol. Econ., 30: 86-91.

Wu, J.P., 2009. Some aspects and considerations on fluctuating prices of the layer egg. Anim. Husbandry Vet. Med., 41: 91-93.

Xie, S., H. Liu and F. Qin, 2013. An analysis of price transmission mechanism among eggs main producing and sales areas. J. China Agric. Univ., 18: 229-234, (In Chinese).

Yang, J., Y. Shi, W. Zhou and Y.S. Che, 2014. Study on detection method for crack in eggs based on computer vision and support vector machine neural network. Applied Mech. Mater., 472: 176-179.

Zhang, Z.Q., Y.L. Jiang and Q. Lu, 2013. Empirical research on effect of egg price fluctuation on the welfare of urban residents with different levels of income. J. Northwest A&F Univ., 13: 43-50.

Zhou, H. and H. Li, 2012. Fluctuations analysis of the price of eggs observed since the 21st century. J. Beijing Univ. Agric., 27: 49-52, (In Chinese).

Zhu, N., Y. Song and J. Ma, 2012. Analysis of the transmission mechanism of price fluctuations in the livestock and poultry product markets of China: A case study on the livestock and poultry products mainly fed with grains. Price Theory Pract., 8: 55-56, (In Chinese).

Zhu, N., Y.H. Song and J. Ma, 2015. Analysis of the urban purchase decision-making behavior based on the brand of chicken eggs and its influencing factors-Take Beijing as an example. Chinese J. Anim. Sci., 51: 35-43, (In Chinese).

Zhu, Z. and M. Ma, 2011. The identification of white fertile eggs prior to incubation based on machine vision and least square support vector machine. Afr. J. Agric. Res., 6: 2699-2704.