Int. J. Biosci. 2014

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 4, No. 12, p. 178-185, 2014

INNSPUB

RESEARCH PAPER

An investigation of relation between CO_2 emissions and yield of tea production in Guilan province of Iran

Farshad Soheili-Fard[1*], **Hamid Reza Ghassemzadeh**[1], **Seyed Babak Salvatian**[2]

[1]*Department of Agricultural Machinery Engineering, Faculty of Agriculture, University of Tabriz, Tabriz, Iran*

[2]*Tea Research Institute, Lahijan, Guilan Province, Iran*

Key words: Linear regression, CO_2 emissions, Cobb-Douglass function, tea, sensitivity analysis.

http://dx.doi.org/10.12692/ijb/4.12.178-185

Abstract

This paper examines the CO_2 emissions patterns and the relationship between CO_2 input and yield for tea production in Lahijan city of Guilan province. Data from 30 farmers were collected using a face-to-face questionnaire method. The results showed that the average of total CO_2 emissions in tea production was 935.98 $kgCO_{2eq.}$ ha^{-1} where the nitrogen with about (26.32%) and diesel fuel with about (26.32%) were the major CO_2 emitter, respectively. Based on three farms size level results, the medium and small farms had the best and worst condition from CO_2 emissions and tea yield point of view. The CO_2 ratio of small, medium, large and total farms was computed as 0.113, 0.079, 0.105 and 0.089 $kgCO_{2eq.}$ kg^{-1}, respectively. In this study, the Cobb-Douglass production function was applied for modeling of CO_2 inputs on tea yield. Econometric assessment results revealed that the CO_2 inputs of phosphate and nitrogen had significant influence on the yield. The impact of phosphate (-2.60) and nitrogen (2.50) were found at the highest among the other input parameters in decreasing and increasing of yield, respectively. Sensitivity analysis indicated that the MPP value of CO_2 inputs was between -24.17 and 66.91. Also the MPP value of nitrogen was the highest among all CO_2 emitter inputs.

* **Corresponding Author:** Farshad Soheili-Fard ✉ farshad_soheilyfard@yahoo.com

Introduction

The tea plant, *Camellia sinensis (L.) O.* Kuntze, family Theaceae, is a small evergreen, perennial, cross-pollinated plant and grows naturally as tall as 15 m. However, under cultivated conditions, a bush height of 60–100 cm is maintained for harvesting the tender leaves (Yemane *et al.,* 2008). The greenhouse gas (GHG) emission issues are also critical in the agricultural production systems. The intensifying global focus on the environmental responsibility has forced industries and policy makers to develop strategies to decrease the production of harmful emissions. Almost 14 percent of global net CO_2 emissions come from agriculture sector. Based on the GHG estimations, it has been estimated that agriculture accounted for 10-12% of the global anthropogenic emission. Hence, calculating GHG emission in the crop production process throughout its whole production cycle (including production, and use of machinery, pesticides and fertilizers) is a useful tool to assess the amount of GHG emission (Pishgar-Komleh *et al.,* 2013). Since management practices affect the emissions of all GHG simultaneously, any mitigation policy must account for the wide range of possible impacts. Therefore, a holistic approach is essential "as it reveals relevant interactions between farm components" (Vergé *et al.,* 2009). Life-cycle analysis (LCA) in potato production is a tool used to assess the amount of greenhouse gas throughout its whole life cycle (includes production, use of machinery and application of agricultural chemicals such as pesticides and fertilizers). Models are the only practical way to quantify the net effect of farm practices on CO_2 emissions or to assess climate change mitigation measures (Dyer *et al.,* 2010). CO_2 emission estimation in agricultural crop production systems has been considered by several authors. Soni *et al.* (2013) considered the energy use index and CO_2 emissions in rainfed agricultural production systems of North East Thailand. In this study, system efficiency, total energy input and corresponding $CO_{2eq.}$ emissions were estimated and compared for different crops. In another study by Koga and Tajima (2011) energy efficiency and GHG emissions under bioethanol-oriented paddy rice production in northern Japan was investigated. They concluded that there are opportunities for further improvement in energy efficiency and reductions in GHG emissions under whole rice plant-based bioethanol production systems. Ho (2011) calculated the CO_2 emissions of wheat production. Nabavi-Pelesaraei *et al.* (2014a) investigated of modeling and optimization of CO_2 emission of tangerine production in Guilan province of Iran using artificial neural networks and data envelopment analysis approach, respectively. In another study, Nabavi-Pelesaraei *et al.* (2014b) examined Cobb-Douglas function production for total CO_2 emissions modeling of rice production based on CO_2 emitter inputs. In other work, the environmental impact assessment modeled using linear regression for wheat production by Khoshnevisan *et al.* (2013).

With respect to above introduction, calculation of CO_2 emissions, determination of functional relation as between CO_2 emissions and yield of tea production in Guilan province of Iran and sensitivity analysis of CO_2 inputs on tea yield was the subjectivity of the present study.

Materials and methods

2.1. Case study and sampling design

The study was conducted in Guilan province, Iran. It is located in the North of Iran, within 36° 34′ and 38° 27′ north latitude and 48° 53′ and 50° 34′ east longitude (Nabavi-Pelesaraei *et al.,* 2014c). In Guilan provinvce, Lahijan city is the one of major tea producers. Lahijan is located in north of Iran on the south coast of the Caspian Sea, 19 m above sea levels. The annual average rainfall is almost 1100 mm. The highest and lowest temperature is 33° and 0° Celsius in summer and winter respectively. The soil analysis showed the structure of the soil is clay and clay loam (Anon, 2013). Guilan province was selected for this research because of its high tea cultivated area (90% of country area). The data used in this study were based on cross sectional and data were collected from 30 farmers growing single tea by using a face-to-face questionnaire. The average size of the studied farms was 0.7 ha. The sample size was determined using the Cochran method (Snedecor and Cochran, 1988).

$$n = \frac{N(s \times t)^2}{(N-1)d^2 + (s \times t)^2} \qquad 1$$

Where n is the required sample size; s, is the standard deviation; t, is the value at 95% confidence limit (1.96); N, is the number of holding in the target population and d, is the acceptable error. For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used. In this study, the sample size was calculated 29 but it was considered to be 30 to ensure the more accuracy.

CO_2 emissions of inputs

For calculation of CO_2 emissions in tea production, the amount of inputs was determined and these values were to multiply corresponding coefficients as shown in Table 1. The CO_2 manufacturer inputs in tea production was included machinery, diesel fuel, chemical fertilizers (nitrogen and phosphate) and biocides. According to the rate of the energy equivalent of machinery (62.7 MJ ha^{-1}), the CO_2 emissions coefficient of machinery was calculated as 4.45 $kgCO_{2eq.}$ h^{-1}. It should be noted, this coefficient was 0.071 $kgCO_{2eq.}$ MJ^{-1} (Dyer and Desjardins, 2006; Nabavi-Pelesaraei *et al.*, 2014b).

In this study, tea farms were classified into 3 categories including a): small farms (<0.5 hectare), b): medium farms (between 0.5 and 1 hectares) and C): large farms (>1 hectare). In order to compare the amount of CO_2 emission between different tea farm size, CO_2 ratio was proposed to be calculated as follows (Khoshnevisan *et al.*, 2014).

$$CO_2 \text{ ratio} = \frac{\text{Total } CO_2 \text{ emissions } (kgCO_{2eq.}\, ha^{-1})}{\text{Tea yield } (kg\, ha^{-1})} \qquad (2)$$

Analysis of CO_2 emissions with mathematical models

The different mathematical functions such as linear, linearlogarithmic, logarithmic-linear and second degree polynomial were tested to find and analyze the relationship between CO_2 inputs and tea yield. Cobb-Douglas function yielded better estimates in terms of statistical significance and expected signs of parameters among other functions.

The Cobb-Douglass production function is expressed as follows:

$$Y = f(x)\exp(u) \qquad 3$$

This function can be expressed as a linear relationship using the following expression:

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \qquad i = 1,2,\ldots,n \qquad 4$$

Eq. (4) can be expressed in the following form:

$$\ln Y_i = \alpha_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + e_i \qquad 5$$

Moreover, the quantity of CO_2 emissions was zero when the amount of inputs use was zero. Accordingly, the constant can be remove in the Eq. (4) and new formula can be written as:

$$\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + e_i \qquad 6$$

Where Xi stands for corresponding CO_2 emissions as X_1, machinery; X_2, diesel fuel; X_3, nitrogen; X_4, phosphate; and X_5, biocides.

In this study the return to scale index was determined in order to analyze the proportional changes in output due to a proportional change in all the inputs (where all inputs increase by a constant factor). So, the return to scale values for the Eqs. (4)-(6) were determined by gathering the elasticities, derived in the form of regression coefficients in the Cobb-Douglas production function. If the sum is more than, equal to, or less than unity, implying that there are increasing, constant, or decreasing returns to scale, respectively (Rafiee *et al.*, 2010).

Sensitivity Analysis

The Marginal Physical Productivity (MPP) technique, based on the response coefficients of the inputs, was used to determine the sensitivity of a particular CO_2 input to production. The MPP of a factor indicates the change in tea with a unit change in the factor input in question, keeping all other factors constant at their geometric mean level.

To calculate MPP, Eq. (7) is used (Mobtaker *et al.*, 2012).

$$MPP_{xj} = \frac{GM(Y)}{GM(X_j)} \times \alpha_j = \frac{GM(P)}{GM(E_j)} \times \alpha_j \qquad 7$$

where MPP_{xj} is the marginal physical productivity of jth input, α_j denote the regression coefficient of jth input, $GM(Y)$ is geometric mean of yield and $GM(X_j)$ denote the geometric mean of jth input CO_2 on per hectare basis, $GM(P)$ geometric mean of production $GM(E_j)$ geometric mean of jth input on farm $(E_{ji} = X_{ij}A_i)$.

Basic information on CO_2 inputs of tea production were entered into Excel 2010 spreadsheets and SPSS 20.0 software program.

Results and Discussion

3.1. CO_2 emissions of tea production

Table 2 showed the results of CO_2 emissions and yield for tea production in Guilan province of Iran based on farm size levels. Accordingly, that the average of total CO_2 emissions and yield was calculated as 622 $kgCO_{2eq.}$ ha^{-1} and 10524.32 kg ha^{-1}, respectively. Medium farms had the best conditions between three groups farms. Because, the total CO_2 emissions had the lowest rate and tea yield had the highest rate among all farms as shown in Table 2. With respect to non-significant difference between farm groups for CO_2 emissions point of view, small farms had the worst condition. Because the CO_2 emissions of tea was a lot and tea yield was very little toward medium and large farms. The reason of these results was associated with differences in the use of nitrogen fertilizers. The rate of CO_2 produced by nitrogen consumption was found to be about 392 $kgCO_{2eq.}$ per hectare; While, the amount of CO_2 emissions was 528 $kgCO_{2eq.}$ and 591 $kgCO_{2eq.}$ for small and large farms from nitrogen, respectively. This large difference arises from lack of knowledge in true pattern. So, it is suggested the all farms (specially small farms) should be close to medium farms in chemical fertilizers consumption (mainly nitrogen) point of view.

The share of each input in total CO_2 emissions is demonstrated in Fig 1. As expected, the nitrogen had the highest share of CO_2 emissions with 49.26%; followed by diesel fuel with 35.89% and machinery with 11.62%. So, the timely maintenance and selection of appropriate machinery can be save the diesel fuel used for tea production and reduction of CO_2 emissions, significantly. Moreover, the promotional activities can be effective in the studied area for CO_2 emissions reduction without reducing yield.

The results of CO_2 ratio are given in Table 3. The results indicated CO_2 ratio of total farms was computed as 0.089 $kgCO_{2eq.}$ kg^{-1}. Also, the small farms (with 0.113 $kgCO_{2eq.}$ kg^{-1}) and medium farms ($kgCO_{2eq.}$ 0.079 kg^{-1}) had the highest and lowest CO_2 ratio, respectively.

Table 1. CO_2 emission coefficients of agricultural inputs.

Input	Unit	CO_2 Coefficient ($kg\ CO_{2eq.}\ unit^{-1}$)	Reference
1. Machinery	MJ	4.45	
2. Diesel fuel	L	2.76	(Dyer and Desjardins, 2003)
3. Chemical fertilizers			
(a) Nitrogen	kg	1.3	(Khoshnevisan *et al.*, 2014)
(b) Phosphate (P_2O_5)	kg	0.2	(Nabavi-Pelesaraei *et al.*, 2014c)
4. Biocides	kg	5.1	(Lal, 2004)

Econometric model estimation of tea production

The relationship between CO_2 inputs and yield was estimated by Cobb-Douglass production function (Eq. (3)). Accordingly, the tea yield (endogenous variable) was assumed to be a function of machinery, diesel fuel, nitrogen, phosphate and biocides (exogenous variables). Autocorrelation test was performed using Durbin-Watson test (Çetin and Vardar, 2008). The test result indicated that the Durbin-Watson value of tea was 2.30 for Eq. (6). So, there was no autocorrelation in the estimated model, indeed each of the inputs are contributed to yield independently. The adjust R² coefficient of tea was found to be 0.99 for this linear regression. The result of regression of this model is shown in Table 4. It can be seen from Table 4 that for tea production, phosphate had the highest impact (-2.60) among other inputs and significantly contributed on the yield at 1% level in negative form. This indicates that with an additional use of 1% for of this CO$_2$ input would lead to 2.60% decrease in tea yield. The other important input was nitrogen with elasticities of 2.50, at 1% significant level. The sum of the regression coefficients or return to scale of the CO$_2$ inputs was calculated as 0.04 for Model 1. This implies that a 1% increase in the total CO$_2$ inputs would lead to only 0.04% increase in the tea yield. So, it can be said the minimize of phosphate had the more than positive effect on tea yield toward the increasing of CO$_2$ inputs in the studied area.

** Indicates significance at 1%.

Nabavi-Pelesaraei *et al.* (2014b) reported that among CO$_2$ emitter inputs, effect of all inputs on rice yield except fuel, nitrogen and phosphate was significant at 1% level and effect of machinery was significant at the 5% level. Also the R² of model was 0.99.

Table 2. CO$_2$ emissions and yield of tea production based on different farm size levels.

Items	Unit	Farm size groups (ha)			Average (unit ha^{-1})
		Small (<0.5)	Medium (0.5-1)	Large (>1)	
A. Inputs					
1. Machinery	kgCO$_{2eq.}$	100.12^{a}	109.88^{b}	109.63^{b}	108.80
2. Diesel fuel	kgCO$_{2eq.}$	324.84^{a}	327.44^{b}	359.19^{c}	335.93
3. Chemical fertilizers	kgCO$_{2eq.}$				
(a) Nitrogen		528.35^{a}	391.96^{b}	591.41^{c}	461.09
(b) Phosphate (P$_2$O$_5$)		15.20^{a}	11.28^{b}	17.02^{c}	13.27
4. Biocides	kgCO$_{2eq.}$	11.75^{a}	18.08^{b}	16.17^{b}	16.90
Total CO$_2$ emissions	kgCO$_{2eq.}$	980.26^{a}	858.63^{a}	1093.42^{a}	935.98
B. Output					
1. Tea yield	kg	8658.32^{a}	10895.06^{b}	10389.99^{b}	10524.34

Note: Different letters show significant difference of means at 5% level.

Table 3. The results of CO$_2$ ratio based on different farm size levels.

Items	CO$_2$ ratio (kgCO$_{2eq.}$ kg^{-1})
Small farms	0.113
Medium farms	0.079
Large farms	0.105
Total farms	0.089

Table 4. Econometric estimation results of CO$_2$ inputs.

Endogenous variable: Tea yield	Coefficient	*t*-ratio
Exogenous variables		
Model 1: $\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + e_i$		
Machinery	0.08	0.54
Diesel fuel	0.03	0.25
Nitrogen	2.50	15.18**
Phosphate (P$_2$O$_5$)	-2.60	-13.47**
Biocides	0.03	0.37
Durbin-Watson	2.30	
Adjust R^2	0.99	
Return to scale ($\sum_{i=1}^{n} \alpha_i$)	0.04	

** Indicates significance at 1%.

MPP results

The sensitivity of CO_2 inputs in tea production was analyzed by using MPP technique based on response coefficient of inputs and Fig 2 displays the MPP results. The major MPP was drawn for the CO_2 of nitrogen (66.91), followed by the phosphate (-24.17) and biocides (23.75). This indicates that additional utilization of 1 $kgCO_{2eq.}$ for each of the nitrogen and phosphate CO_2 would result in an increase and a decrease in yield by 66.91 and -24.17 kg, respectively, showing that these inputs (exogenous parameters) have a strong impact on the yield (endogenous variable) with large sensitivity coefficients.

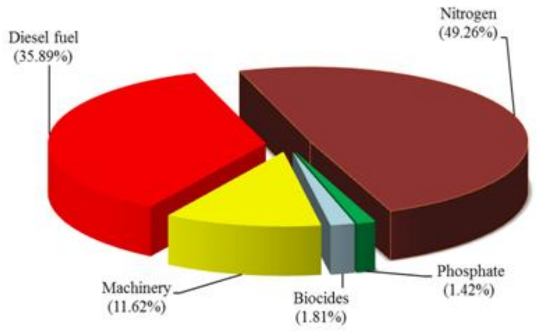

Fig. 1. The share of each input for CO_2 emissions in tea production.

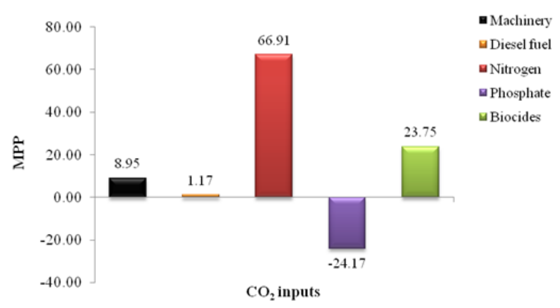

Fig. 2. Sensitivity analysis of CO_2 emissions for tea production in Guilan province, Iran.

Conclusions

Based on the present study the following conclusions are drawn.

The average of total CO_2 emissions and yield of tea production was calculated as 935.98 $kgCO_{2eq.}$ ha^{-1} and 10524.34 kg ha^{-1}, respectively.

With respect to three farm groups, the lowest CO_2 emissions and highest tea yield were belonged to medium farms among all tea farms in the studied area.

The highest share of CO_2 emissions was belonged to nitrogen with 49.26%; followed by diesel fuel with 35.89% and machinery with 11.62%.

The CO_2 ratio of small, medium, large and total farms was computed as 0.113, 0.079, 0.105 and 0.089 $kgCO_{2eq.}$ per one kg of tea yield, respectively.

5- The impact of phosphate and nitrogen were significantly positive and negative on tea yield ($p < 1\%$), respectively.

The return to scale results revealed that CO_2 emissions for tea production was increasing returns to scale in the low value. That means an increase in the total inputs may result in an increase in output in greater proportion than the input increase.

Among CO_2 emissions sources, nitrogen and phosphate had the highest MPP value with positive and negative effect.

Acknowledgment

The financial support provided by the University of Tabriz, Iran, is duly acknowledged. Also, I want to express my deep appreciation of all Mr. Ashkan Nabavi-Pelesaraei's efforts to help me revise the study.

References

Anonymous. 2013. Annual Agricultural Statistics. Ministry of Jihad-e-Agriculture of Iran. http://www.maj.ir, [in Persian].

Çetin C, Vardar A. 2008. An economic analysis of energy requirements and input costs for tomato production in Turkey. Renewable Energy **33(3)**, 428-433.
http://dx.doi.org/10.1016/j.renene.2007.03.008

Dyer JA, Desjardins RL. 2003. Simulated farm fieldwork, energy consumption and related greenhouse gas emissions in Canada. Biosystems Engineering **85(4),** 503-513. http://dx.doi.org/10.1016/S1537-5110(03)00072-2

Dyer JA, Desjardins RL. 2006. Carbon dioxide emissions associated with the manufacturing of tractors and farm machinery in Canada. Biosystems Engineering **93(1),** 107-118. http://dx.doi.org/10.1016/j.biosystemseng.2005.09.011

Dyer JA, Kulshreshtha SN, McConkey BG Desjardins RL. 2010. An assessment of fossil fuel energy use and CO_2 emissions from farm field operations using a regional level crop and land use database for Canada. Energy **35,** 2261-2269. http://dx.doi.org/10.1016/j.energy.2010.02.013

Ho JA. 2011. Calculation of the carbon footprint of Ontario wheat. Guelph Publication **4(2),** 49-55.

Khoshnevisan B, Rafiee S, Omid M, Mousazadeh H. 2013. Regression modeling of field emissions in wheat production using a life cycle assessment (LCA) approach. Electronic Journal of Energy & Environment **1(2),** 9-19.

Khoshnevisan B, Shariati H.M, Rafiee S, Mousazadeh H. 2014b. Comparison of energy consumption and GHG emissions of open field and greenhouse strawberry production. Renewable and Sustainable Energy Reviews **29,** 316-324. http://dx.doi.org/10.1016/j.rser.2013.08.098

Koga N, Tajima R. 2011. Assessing energy efficiencies and greenhouse gas emissions under bioethanol-oriented paddy rice production in northern Japan. Journal of Environmental Management **92,** 967–973. http://dx.doi.org/10.1016/j.jenvman.2010.11.008

Lal R. 2004. Carbon emission from farm operations. Environment International **30(7),** 981-990. http://dx.doi.org/10.1016/j.envint.2004.03.005

Mobtaker HG, Akram A, Keyhani A. 2012a. Energy use and sensitivity analysis of energy inputs for alfalfa production in Iran. Energy for Sustainable Development **16,** 84-89. http://dx.doi.org/10.1016/j.esd.2011.10.009

Nabavi-Pelesaraei A, Kouchaki-Penchah H, Amid S. 2014a. Modeling and optimization of CO_2 emissions for tangerine production using artificial neural networks and data envelopment analysis. International Journal of Biosciences **4(7),** 148-158. http://dx.doi.org/10.12692/ijb/4.7.170-183

Nabavi-Pelesaraei A, Abdi R, Rafiee S. 2014b. Modeling and optimization of greenhouse gas emissions for rice production in Langroud city of Guilan province. The 8th National Congress on Agricultural Machinery Engineering (Biosystem) & Mechanization, Ferdowsi University of Mashhad, Iran.

Nabavi-Pelesaraei A, Abdi R, Rafiee S, Mobtaker HG. 2014c. Optimization of energy required and greenhouse gas emissions analysis for orange producers using data envelopment analysis approach. Journal of Cleaner Production **65,** 311-317. http://dx.doi.org/10.1016/j.jclepro.2013.08.019

Pishgar-Komleh SH, Omid M, Heidari MD. 2013. On the study of energy use and GHG (greenhouse gas) emissions in greenhouse cucumber production in Yazd province. Energy **59,** 63-71. http://dx.doi.org/10.1016/j.energy.2013.07.037

Rafiee S, Mousavi-Avval SH, Mohammadi A. 2010. Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy **35,** 3301-3306. http://dx.doi.org/10.1016/j.energy.2010.04.015

Snedecor GW, Cochran WG. 1989. Statistical methods. 8th ed. US: Iowa State Press.

Soni P, Taewichit C, Salokhe V. 2013. Energy consumption and CO_2 emissions in rainfed

agricultural production systems of Northeast Thailand. Agricultural Systems **116,** 25-36.
http://dx.doi.org/10.1016/j.agsy.2012.12.006

Vergé XPC, Dyer JA, Desjardins RL, Worth D. 2009. Greenhouse gas emissions from the Canadian pork industry. Livestock Science **121,** 92-101.
http://dx.doi.org/10.1016/j.livsci.2008.05.022

Yemaneh M, Chandravanshi BS, Wondimu T. 2008. Levels of essential and non-essential metals in leaves of the tea plant (*Camellia sinensis L.*) and soil of Wushwush farms, Ethiopia. Food Chemistry **107,** 1236-1243.
http://dx.doi.org/10.1016/j.foodchem.2007.09.058