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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan  
Mob: +92 300 3008585, Fax: +92 41 8815544  
E-mail: editorijps@gmail.com

## Effects of Adding Different Dietary Levels of Garlic (*Allium sativum*) Powder on Productive Performance and Egg Quality of Laying Hens

Abdulaziz A. Al Aqil

Department of Animal and Fish Production, King Faisal University,  
Al-Ahsa, 31982, Kingdom of Saudi Arabia

**Abstract:** The present study was conducted to evaluate the effect of adding different dietary levels of garlic (0, 0.4, 0.8, 1.0%) powder on productive performance and egg quality of laying hens from 52 to 60 weeks of age. Two hundred 52 week old Hisex laying hens were randomly distributed among four treatments with ten replicates with five hens per each replicate. Body weight gain, egg production, feed consumption, feed conversion ratio, egg weight, egg mass, egg specific gravity, Haugh units and egg yolk color were measured. Results showed no significant effects on body weight gain, egg weight and Haugh unit for hens fed diets containing 0, 0.4, 0.8, or 1.0% garlic powder. Feed consumption and egg production of hens fed diets containing 0.8 and 1.0% decreased significantly than those fed diets containing 0 and 0.4% garlic powder. Hens fed diets containing 0.4, 0.8 and 1.0% garlic powder showed lower (better) feed conversion ratio and lower egg yolk color than those fed diets containing 0.0% garlic powder. In addition, hens fed diets containing 0.4, 0.8 and 1.0% garlic powder showed higher egg mass than those fed diets containing 0.0% garlic powder. Hens fed diets containing 0.8% garlic powder showed higher egg specific gravity than those fed diets containing 0.0% garlic powder. It was concluded that adding 1.0% garlic powder into laying hen diets had some positive effects on productive performance and egg quality parameters from 52 to 60 weeks of age.

**Key words:** Egg quality, egg production, garlic powder, laying hens, productive performance

### INTRODUCTION

Using synthetic antibiotics as growth promoters in poultry diets were banned to avoid their adverse effects on animal and human health throughout their residual problems in poultry products and bacterial resistance (Wegener *et al.*, 1998). Therefore, poultry nutritionists have been searching for natural non-antibiotic feed additives to replace antibiotics and to use in poultry and animal nutrition (Lopez-Bote *et al.*, 1998; Hertrampf, 2001; Zheng and Wang, 2001; Humphrey *et al.*, 2002; Miura *et al.*, 2002; Burt and Reinders, 2003; Jamroz *et al.*, 2005). Garlic is one of the phytochemical alternatives which can be used as natural feed additives in poultry nutrition. Garlic (*Allium sativum* Linn) had been used as traditional folklore medicine in many countries. Some studies claimed that garlic contains many bioactive components responsible for smell of garlic such as alliin, diallylsulphides and allicin (Murad and Baseer, 1997; Amagase *et al.*, 2001). In addition, some studies reported many beneficial effect for garlic on humans and animals health (Bordia *et al.*, 1975; Shoetan *et al.*, 1984; Reddy *et al.*, 1991; Warshafsky *et al.*, 1993; Silagy and Neil, 1994; Alder and Holub, 1997; Konjufca *et al.*, 1997; Berthold *et al.*, 1998; McCrindle *et al.*, 1998; Mottaghitlab and Taraz, 2002). On the other hand, Khan *et al.* (2007) noted that garlic powder contains about 13.12% crude protein, 2.0% ether extract, 35.5% crude fiber and 2.5% total ash on dry

matter basis. There is a limited number of studies which had evaluated the effects of adding different dietary levels of garlic powder on the productive performance and egg quality of laying hens. Therefore, this study was carried out to determine the effects of adding different dietary levels (0.0, 0.4, 0.8, and 1.0%) of garlic powder on productive performance and egg quality of laying hens from 52 to 60 weeks of age.

### MATERIALS AND METHODS

Commercial dried garlic powder was purchased from local market in Al-Ahsa, Kingdom of Arabia Saudi.

**Experimental design:** The present study was conducted to evaluate the effect of adding different dietary levels of dried garlic powder on productive performance and egg quality of laying hens from 52 to 60 weeks of age. Two hundred Hisex laying hens at 52 weeks age with similar body weight and egg production were randomly distributed and reared in battery group cages (100 x 60 x 30 cm<sup>3</sup>) in a close sided laying hen house among four dietary treatments with ten replicates with five hens per each replicate. Hens were fed layer diets containing either 0.0, 0.4, 0.8, or 1.0% garlic powder. The layer diets used in this study were calculated to be isocloric and isonitrogenous with an average of 2762 Kcal metabolizable energy and 16.89% crude protein, respectively to meet the nutrient requirements of Hisex

laying hens as shown in Table 1. Each hen was received 120 g once daily and water was provided to all hens *ad libitum*. All hens received 16 hours light daily during experimental period.

**Measurements:** The initial body weight of laying hens was individually measured at the beginning of the experimental study at 52 weeks of age and the final body weight was recorded at the end of the experimental study at 60 weeks of age. Egg production (%), feed consumption (kg), feed conversion ratio (kg feed consumed/kg egg mass) were recorded. Three eggs were collected during the last 3 consecutive day at biweekly intervals from each replicate and individually weighed to the nearest 0.01 g to measure egg weight. Then, the same eggs were stored overnight at room temperature before egg specific gravity was determined according to Harms *et al.* (1990) using saline solutions ranged from 1.060 to 1.10 g/mL in increments of 0.005. Albumen height was measured with an Ames micrometer (model S-6428, Ames, Waltham, MA) at a point halfway between the egg yolk and the edge of the widest expanse of egg albumen (USDA, 2000). Haugh units were calculated as follows:

$$\text{Haugh unit} = 100 \times \log (\text{AH} + 7.57 - 1.7\text{EW}^{0.37})$$

where, AH is albumin height of the inner thick albumen (mm) and EW is egg weight (g) (Panda, 1996). Egg yolk color was measured using Roche color fan.

**Statistical analysis:** Data obtained were subjected to one-way ANOVA using the GLM procedure of a statistical software package (SPSS 18.0, SPSS Inc., Chicago, IL). Experimental units were based on replicate averages. Treatment means were expressed as mean±standard error of means (Mean±SEM) and separated ( $p \leq 0.05$ ) using the Duncan's multiple range test (Duncan, 1955).

## RESULTS AND DISCUSSION

The present study was conducted to evaluate the effect of adding different dietary levels of garlic (0.0, 0.4, 0.8, and 1.0%) powder on productive performance and egg quality of laying hens from 52 to 60 weeks of age. Results obtained from the present study showed no significant effects on body weight gain, egg weight and Haugh unit for hens fed diets containing 0, 0.4, 0.8, or 1.0% garlic powder. Feed consumption and egg production of hens fed diets containing 0.8 and 1.0% decreased significantly than those fed diets containing 0 and 0.4% garlic powder. However, no significant differences were observed in feed consumption and egg production for hens fed diets containing 0 and 0.4% garlic powder. The reduction in feed consumption for laying hens fed diets containing garlic powder at the levels of 0.4, 0.8 or 1.0% indicated affect the aroma, the

Table 1: Composition experimental diets

Feed ingredients	(%)
Yellow corn	62.0
Corn oil	1.0
Dehulled soybean meal (44.5% CP)	26.4
Limestone	8.7
Dicalcium phosphate	1.0
Antioxidant	0.10
L-Lysine	0.10
Choline chloride	0.10
DL-Methionine	0.10
Vitamin-mineral premix*	0.25
Salt	0.25
<b>Calculated nutritional composition</b>	
Dry matter (%)	90.27
Energy (Kcal ME/kg feed)	2762
Crude protein (%)	16.89
Crude fat (%)	2.65
Crude fiber (%)	3.30
Linolenic acid (%)	1.57
Calcium (%)	3.62
Available phosphorus (%)	0.31

\*Vitamin-mineral premix added at this rate yields: 149.60 mg Mn, 16.50 mg Fe, 1.70 mg Cu, 125.40 mg Zn, 0.25 mg Se, 1.05 mg I, 11,023 IU vitamin A, 46 IU vitamin E, 3,858 IU vitamin D<sub>3</sub>, 1.47 mg minadione, 2.94 mg thiamine, 5.85 mg riboflavin, 20.21 mg pantothenic acid, 0.55 mg biotin, 1.75 mg folic acid, 478 mg choline, 16.50 µg vitamin B<sub>12</sub>, 45.93 mg niacin and 7.17 mg pyridoxine per kg diet

palatability of the diets and the appetite of the laying hens. Also, the reduction in egg production for laying hens fed diets containing garlic powder at the levels of 0.4, 0.8 or 1.0% compared with those fed diets containing 0.0% garlic might be attributed to the reduction in feed consumption. Hens fed diets containing 0.4, 0.8 and 1.0% garlic powder showed lower (better) feed conversion ratio and lower egg yolk color than those fed diets containing 0.0% garlic powder. However, no significant differences were observed in feed conversion ratio and egg yolk color among hens fed diets containing 0.4, 0.8 and 1.0% garlic powder. The improvements in feed conversion ratios for hens fed diets containing 0, 0.4 and 1.0% garlic powder compared with those fed diets containing 0.0% garlic might be attributed to the increasing in egg mass and the improvement of digestive enzymes secretion.

In contrast, hens fed diets containing 0.4, 0.8 and 1.0% garlic powder showed higher egg mass than those fed diets containing 0.0% garlic powder. However, no significant differences were observed in egg mass among hens fed diets containing 0.4, 0.8 and 1.0% garlic powder. Hens fed diets containing 0.8% garlic powder showed higher egg specific gravity than those fed diets containing 0.0% garlic powder, but were not different from hens fed diets containing 0.4 and 1.0% garlic powder as shown in Table 2. The positive effect observed in the present study for adding garlic powder into laying hen diets on feed conversion ratio and egg

Table 2: Effect of adding different dietary levels (0, 0.4, 0.8 and 1.0%) of garlic powder on productive performance and egg quality of laying hens from 52 to 60 weeks of age

	Garlic powder (%)			
	0	0.4	0.8	1.0
Initial body weight (g)	1390.21±24.94	1377.35±17.43	1412.53±41.27	1392.75±16.93
Body weight gain (g)	89.99±38.73	143.656±32.93	100.87±42.877	183.85±10.37
Egg production (%)	60.37±2.42 <sup>a</sup>	51.25±2.15 <sup>b</sup>	40.06±2.99 <sup>c</sup>	39.12±1.97 <sup>c</sup>
Egg weight (g)	67.73±0.87	66.20±1.21	64.07±1.34	63.87±1.65
Feed consumption (kg)	5.78±0.01 <sup>a</sup>	5.16±0.11 <sup>b</sup>	4.84±0.08 <sup>c</sup>	4.79±0.08 <sup>c</sup>
Feed conversion ratio (kg feed/kg egg mass)	2.54±0.09 <sup>a</sup>	1.97±0.02 <sup>b</sup>	1.91±0.02 <sup>b</sup>	1.90±0.06 <sup>b</sup>
Egg mass (kg)	2.29±0.08 <sup>b</sup>	2.62±0.05 <sup>a</sup>	2.54±0.05 <sup>a</sup>	2.53±0.07 <sup>a</sup>
Egg specific gravity (g/cm <sup>3</sup> )	1.07±0.00 <sup>b</sup>	1.07±0.00 <sup>ab</sup>	1.08±0.00 <sup>a</sup>	1.07±0.00 <sup>ab</sup>
Egg yolk color	4.67±0.15 <sup>a</sup>	3.60±0.34 <sup>b</sup>	3.73±0.27 <sup>b</sup>	3.07±0.13 <sup>b</sup>
Haugh unit	87.79±2.56	86.15±1.69	90.19±2.75	87.90±1.69

<sup>a-c</sup>Means±standard error of mean within a row that do not share a common superscript are significantly different (p<0.05)

mass and egg specific gravity might be attributed to allicin (active component) found in garlic powder which inhibits the growth of pathogenic bacteria.

There were differences in the productive performances and egg quality of laying hens fed diets containing garlic in the previous studies. While in a study, egg production, egg mass, body weight gain, feed consumption, egg weight, feed conversion ratio were not affected by adding 0.2% garlic oil into Babcock B-300 laying hen strain diets for 8 weeks (Reddy *et al.*, 1991). Birrenkott *et al.* (2000) found no differences in egg yolk color for hens fed diets containing up to 3% dietary level of garlic powder. In another study, Ashfaq (2001) reported no significant effect on egg weight after adding garlic powder into laying hen diets. Chowdhury *et al.* (2002) also reported no effect on body weight gain, egg production, egg weight, egg mass, feed consumption and feed conversion ratio when laying hens fed diets supplemented with 0, 2, 4, 6, 8 and 10% garlic paste from 28 to 34 weeks of age. Moreover, they found that egg production was significantly higher in the Babcock strain in comparison with other strains (Hisex Brown, ISA Brown, Lohmann, Starcross and Starcross-579 strains). El-Kaiaty *et al.* (2002) observed that adding 2% garlic powder into White Bovans laying hen diets from 30 to 38 weeks of age did not affect body weight, egg production, egg weight and feed conversion ratio, but significantly affected egg mass and feed consumption. Also, Yalcin *et al.* (2006) reported that adding 0, 0.5, 1.0% garlic powder into the diets of SHSY-type brown laying hens from 21 to 43 weeks of age did not affect body weight gain, egg production, feed consumption, feed conversion ratio and Haugh unit. However, they found that egg weight increased with increasing the different dietary levels of garlic powder supplemented. Khan *et al.* (2007) noted significant effects on body weight gain and egg production, but no effect on feed consumption, feed conversion ratio, egg weight and egg mass with increasing levels of adding garlic powder from 0, 2, 6, to 8% into White Leghorn laying hen diets from 30 to 36 weeks of age. Safaa (2007) studied the effect of adding dietary garlic at the level of 2% on the

productive performance of Lohmann Brown laying hens from 31 to 35 weeks of age and found that adding 2% dietary level of garlic had no significant effect on body weight gain, egg production, egg weight, egg mass, feed consumption and feed conversion ratio, but increased Haugh units from 31 to 35 weeks of age and increased egg yolk color at 33 weeks of age. Also, Khan *et al.* (2008) noted that adding 0, 2, 6 and 8% garlic powder into native Desi laying hen diets for 6 weeks exhibited higher egg production and body weight gain with increasing levels of dietary garlic than those fed control diets. However, they reported that feed consumption, feed conversion ratio, egg weight and egg mass were not affected. Recently, Ao *et al.* (2010) noted no differences in egg production and egg weight for ISA Brown laying hens fed diets containing 0, 2, or 3% fermented garlic powder from 41 to 46 weeks of age. They observed that egg yolk color was greater for laying hens fed diets containing 2 and 3% fermented garlic powder than those fed containing 0.0% fermented garlic powder for 5 weeks. Also, they found an increase in Haugh unit by increasing adding fermented garlic powder.

On the other hand, a study conducted by El-Habbak *et al.* (1989) reported an increasing in egg weight and a reduction in egg production for Japanese quail laying hen fed diets containing ethanol extracted garlic. Also, Samanta and Dey (1991) noted an increasing in body weight gain and egg production of Japanese quails fed diets containing garlic powder without effects on feed consumption and feed conversion ratio. Yalcin *et al.* (2007) reported that adding 0, 0.5, 1.0% garlic powder into the diets of Japanese quail laying hens from 9 to 30 weeks of age did not affect body weight gain, egg production, feed consumption, feed conversion ratio and Haugh unit. However, they found that egg weight increased with increasing the dietary level of garlic powder. In addition, Canogullari *et al.* (2010) noted significant improvements in feed consumption, feed conversion ratio, Haugh unit and egg production, but no significant effect on egg weight and body weight gain for laying Japanese quail fed 1.0% garlic powder compared

with those fed 0, 2, 4% garlic powder over 12 weeks. They found that hens fed diets containing 4% showed the poorest feed conversion ratio and egg production. The variations in the effects of adding garlic into laying hen diets among the different studies might be attributed to the differences in the percentages and periods of garlic supplementation, the garlic sources, the stability of active compounds, the age and strains of laying hens used, the preparation methods for garlic used (organic solution or alcohol extraction, drying methods, and etc.), the garlic products used, and the experimental methods used.

**Conclusions:** It was concluded that adding 1.0% garlic powder into laying hen diets had some positive effects on productive performance and egg quality parameters from 52 to 60 weeks of age.

## REFERENCES

- Alder, A.J. and B.J. Holub, 1997. Effect of garlic and fish-oil supplementation on serum lipid and lipoprotein concentrations in hypercholesterolemic men. *Am. J. Clin. Nutr.*, 65: 445-450.
- Amagase, H., B.L. Petesch, H. Matsuura, S. Kasuga and Y. Itakura, 2001. Intake of garlic and its bioactive components. *J. Nutr.*, 131: 955-962.
- Ao, X., J.S. Yoo, J.H. Lee, H.D. Jang, J.P. Wang, T.X. Zhou and I.H. Kim, 2010. Effects of fermented garlic powder on production performance, egg quality, blood profiles and fatty acids composition of egg yolk in laying hens. *Asian-Aust. J. Anim. Sci.*, 23: 786-791.
- Ashfaq, M., 2001. Effect of a dietary mixture of garlic powder (*Allium sativum*) and ground kalongi (*Nigella sativa*) on the performance of layers. M.Sc. Thesis, Faculty of Animal Husbandry, Univ. Agric., Faisalabad, Pakistan.
- Berthold, H.K., T. Sudhop and K. Von Bergmann, 1998. Effects of a garlic oil preparation on serum lipoproteins and cholesterol metabolism. *J. Am. Med. Assoc.*, 279: 1900-1902.
- Birrenkott, G., G.E. Brockenfelt, M. Owens and E. Halpin, 2000. Yolk and blood cholesterol levels and organoleptic assessment of eggs from hens fed a garlic-supplemented diet. *Poult. Sci.*, 79: 75 (Abstract).
- Bordia, A., H.C. Bansal, S.K. Arora and S.V. Singal, 1975. Effect of the essential oils of garlic and onion on alimentary hyperlipemia. *Atherosclerosis*, 21: 15-18.
- Burt, S.A. and R.D. Reinders, 2003. Antibacterial activity of selected plant essential oils against *Escherichia coli* O157: H7. *Lett. Appl. Microbiol.*, 36: 162-167.
- Canogullari, S., M. Baylan, Z. Erdogan, V. Duzguner and A. Kucukgul, 2010. The effects of dietary garlic powder on performance, egg yolk and serum cholesterol concentrations in laying quails. *Czech J. Anim. Sci.*, 55: 286-293.
- Chowdhury, S.R., S.D. Chowdhury and T.K. Smith, 2002. Effects of dietary garlic on cholesterol metabolism in laying hens. *Poult. Sci.*, 81: 1856-1862.
- Duncan, D.B., 1955. Multiple ranges and multiple F test. *Biometrics*, 11: 1-42.
- El-Kaiaty, A.M., A.Z.M. Soliman and M.S.H. Hassan, 2002. The physiological and immunological effects of some natural feed additives in layer hen diets. *Egypt. Poult. Sci.*, 22: 175-203.
- El-Habbak, M.M., E. Saleh, M.S. Arbid, A.G. Hegazi and H. Sofi, 1989. Influence of garlic (*Allium sativum*) on some biological and biochemical changes in Japanese quails with special reference to its hypocholesterolaemic activity. *Archivfur Geflugelkunde*, 53: 73-79.
- Harms, R.H., A.F. Rossi, D.R. Sloan, R.D. Miles and R.B. Christmas, 1990. A method for estimating shell weight and correcting specific gravity for egg weight in eggshell quality studies. *Poult. Sci.*, 69: 48-52.
- Hertrampf, J.W., 2001. Alternative antibacterial performance promoters. *Poult. Int.*, 40: 50-52.
- Humphrey, B.D., N. Huang and K.C. Klasing, 2002. Rice expressing lactoferrin and lysozyme has antibiotic-like properties when fed to chicks. *J. Nutr.*, 132: 1214-1218.
- Jamroz, D., A. Wiliczekiewicz, T. Werteleck., J. Orda and J. Sukorupinska, 2005. Use of active substances of plant origin in chicken diets based on maize and locally grown cereals. *Br. Poult. Sci.*, 46: 485-493.
- Khan, S.H., R. Sardar and M.A. Anjum, 2007. Effects of dietary garlic on performance and serum and egg yolk cholesterol concentration in laying hens. *Asian-Aust. J. Anim. Sci.*, 1: 22-27.
- Khan, S.H., S. Hasan, R. Sardar and M.A. Anjum, 2008. Effects of dietary garlic powder on cholesterol concentration in native desi laying hens. *Am. J. Food Technol.*, 3: 207-213.
- Konjufca, V.H., G.M. Pesti and R.I. Bakalli, 1997. Modulation of cholesterol levels in broiler meat by dietary garlic and copper. *Poult. Sci.*, 76: 1264-1271.
- Lim, K.S., S.J. You, B.K. An and C.W. Kang, 2006. Effects of dietary garlic powder and copper on cholesterol content and quality characteristics of chicken eggs. *Asian-Aust. J. Anim. Sci.*, 19: 582-586.
- Lopez-Bote, C.J., J.I. Gray, E.A. Gomaa and C.I. Flegal, 1998. Effect of dietary administration of oil extracts from rosemary and sage on lipid oxidation in broiler meat. *Br. Poult. Sci.*, 39: 235-240.
- McCrintle, B.W., E. Helden and W.T. Corner, 1998. Garlic extracts therapy in children with hypercholesterolemia. *Arch. Pediatr. Adolesc. Med.*, 152: 1089-1094.
- Miura, K., H. Kikuzaki and N. Nakatani, 2002. Antioxidant activity of chemical components from sage (*Salvia officinalis* L.) and oregano (*Thymus vulgaris* L.) measured by the oil stability index method. *J. Agric. Food Chem.*, 50: 1845-1851.

- Mottaghtalab, M. and Z. Taraz, 2002. Effects of garlic (*Allium sativum*) on egg yolk and blood serum cholesterol in Aryan breed laying hens. *Br. Poult. Sci.*, 43: 42-43.
- Murad, K. and A. Baseer, 1997. Garlic (*Allium sativum*): A review of controlled studies. *Hamdard Medicus*, 11: 4.
- Panda, P.C., 1996. Shape and Texture. In: Text book on egg and poultry technology, P.C. (Ed.), Vikas Publishing House Pvt. Ltd., New Delhi, India.
- Reddy, R.V., S.F. Lightsey and D.V. Maurice, 1991. Effect of feeding garlic oil on performance and egg yolk cholesterol concentration. *Poult. Sci.*, 70: 2006-2009.
- Safaa, S.M.H., 2007. Effect of dietary garlic or fenugreek on cholesterol metabolism in laying hens. *Egypt. Poult. Sci.*, 27: 1207-1221.
- Samanta, A.R. and A. Dey, 1991. Effect of feeding garlic (*Allium sativum* Linn.) as a growth promoter in Japanese quails (*Coturnix coturnix japonica*) and its influence on dressing parameters. *Ind. J. Poult. Sci.*, 26: 142-145.
- Shoetan, A., K.T. Augusti and P.K. Joseph, 1984. Hypolipidemic effects of garlic oil in rats fed ethanol and a high lipid diet. *Exp.*, 40: 261-263.
- Silagy, C. and A. Neil, 1994. Garlic as a Lipid-Lowering Agent. In: A Meta-Analysis, Coll, J.R. (Ed.). Physicians, London, pp: 39-45.
- Warshafsky, S., R.S. Kamer and S.L. Sivak, 1993. Effects of garlic on total serum cholesterol. A meta-analysis. *Ann. Intern. Med.*, 119: 599-605.
- Wegener, H.C., F.M. Aarestrup, L.B. Jensen, A.M. Hammerum and F. Bager, 1998. The association between the use of antimicrobial growth promoters and development of resistance in pathogenic bacteria towards growth promoting and therapeutic antimicrobials. *J. Anim. Feed Sci.*, 7: 7-14.
- USDA, 2000. Subject: Egg-grading manual. Agriculture Handbook Number 75. <http://www.ams.usda.gov/poultry/pdfs/EggGrading%20manual.pdf> Accessed Apr. 2004.
- Yalcin, S., E.E. Onbasilar, Z. Reisli and S. Yalcin, 2006. Effect of garlic powder on the performance, egg traits and blood parameters of laying hens. *J. Sci. Food Agric.*, 86: 1336-1339.
- Yalcin, S., I. Onbasilar, A. Sehu and S. Yalcin, 2007. The Effects of dietary garlic powder on the performance, egg traits and blood serum cholesterol of laying quails. *Asian-Aust. J. Sci.*, 20: 944-947.
- Zheng, W. and S.Y. Wang, 2001. Antioxidant activity and phenolic compounds in selected herbs. *J. Agric. Food Chem.*, 49: 5165-5170.