As. J. Food Ag-Ind. **2010**, 3(03), 319-327

OPEN ACCESS

Asian Journal of Food and Agro-Industry

ISSN 1906-3040

Available online at www.ajofai.info

Research Article

Effects of purple field corn anthocyanins on broiler heart weight

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This paper was originally presented at the International Conference on the Role of Universities in Hands-On Education, Chiang Mai, Thailand, August 2009.

Abstract

Purple field corn (*Zea mays* L.) contains anthocyanins in the grain pericarp and corncob. Several studies undertaken by RMUTL Thailand have shown that purple field corn anthocyanins were not harmful on the productive performance, egg quality and carcass quality in Japanese quail and laying hens. For bioactivity, preliminary evidence of crude extracts of anthocyanins from purple field corncob inhibited growth of *Aspergillus flavus* and *Aspergillus niger*. This experiment used four levels of purple field corn (20, 30, 40 and 60%) as energy sources in broiler rations. These feeding trials were compared with yellow corn for carcass quality. Nine hundred chicks were fed at one day of age. At 42 days of age, six hundred of the birds were random selected and slaughtered to evaluate percentage of carcass, visceral organs and abdominal fat (% of live body weight). The randomized complete block design (RCBD) was tested with 5 treatments and 2 replicates (male and female birds) of 60 birds each. Within sex results were significant ($P<0.05$) in terms of average percentage of drumstick, breast fillet, gizzard and were highly significant ($P<0.01$) in the shank. No significant ($P>0.05$) effects on dressing percentage, liver, gizzard, spleen, bursa gland, winglet (upper wing), wing drumette (lower wing), thigh, shank, breast and breast fillet were detected, except for heart weight and abdominal fat. The percentage of heart weight was highly significant ($P<0.01$) reducing with increased purple field corn level in diets. This paper showed that purple field corn anthocyanins may be useful for heart health.

Keywords: animal feed, poultry, *Zea mays*, carcass quality, heart weight, Thailand

Introduction

Anthocyanins are purple flavonoid pigments that are synthesized in many vegetative plant organs, including leaf, stem anthers, glumes of the cob tassel, coleoptiles and the aleurone layer of maize [1]. In maize, anthocyanins are mutations in flavonoid biosynthetic genes on kernel colour providing the first evidence of chromosome breakage by x-rays and transposable elements which was reviewed by MacClintock [2]. The major anthocyanin showing high activity was cyanidin 3-*O*-β-D-glucoside or C3G [3]. The other anthocyanins are pelargonidin 3-*O*-β-D-glucoside, peonidin 3-*O*-β-D-glucoside, cyaniding 3-*O*-β-D-(6-malonyl-glucoside), pelargonidin 3-*O*-β-D-(6-malonyl-glucoside) and peonidin 3-*O*-β-D-(6-malonyl-glucoside). The cyanidin derivatives constitute around 70% in purple corn seed [4]. Anthocyanins in purple corn have been reported to have various biological activities, such as antibacterial, antifungal activity, antioxidant, antimutagenic, the prevention of obesity, diabetes, ameliorating hyperglycemia in mice [5], and have higher antioxidant properties than blueberries [6]. Thus, purple corn can play a role in functional food and may be also useful as a contributor to food safety. Purple corn has never been used commercially as an energy source in animal diets in Thailand. Amnueysit, *et. al*. [7] used purple field corn as a new component in feed of Japanese male quails (*Coturnix japonica*) and Japanese laying quails. It did not exert any effect on performance, carcass, egg performance and egg quality of Japanese laying quails. Except for yolk colour, the purple field corncob meal had less pigmentation equal to broken rice [8]. The 20, 30, 40 and 60% supplements of purple field corn and yellow corn were used in laying hen diets for 5 periods (28 days per period). The result showed that the laying performance and egg quality were not significantly different [9]. The analysis of amylose starch (%) by absorbance at 610 nm in purple field corn from The Purple Field Corn Breeding Program of Rajamangala University of Technology Lanna in Phitsanuloke, Thailand and yellow corn grains were 21.50 and 21.74; amylopectin (%) were 78.50 and 78.26, respectively. Amino acid and fatty acid analysis were similar. It was noted especially that lysine methionine tryptophan and tyrosine in purple field corn were higher than yellow corn. Analysis of saturated and unsaturated fatty acids in grain of purple field corn and yellow corn were similar [10]. The coefficient of digestibility, biological value (BV), net protein utilization (NPU), AME of purified diet and AME of purple field corn were not significantly different between borrow and gilt crossbred. However, these values were similar to yellow corn [11]. Amnueysit *et. al*. reported the crude extract anthocyanins of purple field corncob at concentrations of 20, 30 and 40% had significant efficacy ($P<0.01$) for antifungal activity against *A. flavus and A. niger* [12].

Materials and Methods

Experimental animals and management

The purple field cornwas developed by Rajamangala University of Technology Lanna, Thailand. The 900 birds, 1–day-old Cob chickens, were allotted to five dietary treatments, six replicate pens (30 birds each). The OPV-PFC was used as the energy source in grower broilers feed at 20, 30, 40 and 60% and compared to feeding with yellow corn. The diets were formulated to exceed recommendations of the NRC [13]. All treatments were given as isocaloric and isonitrogenous diets. Feed and water were supplied *ad libitum* during the 42 days of the study. After the live scan, twenty birds (ten male and ten female birds) per replication were euthanized by cervical dislocation for carcass data. Six hundred of the birds were randomly selected and slaughtered to evaluate the percentage of carcass, dressing percentage, alimentary tract, liver, gizzard, spleen, heart, bursa gland, abdominal fat, winglet (upper wing), wing drumette (lower wing), thigh, shank, breast, breast filet and abdominal fat (% of live body weight).

Statistical analysis

Two factors without replication, randomized completely block design (RCBD), tested with 5 treatments and 2 replicates (male and female bird) of 60 birds each. These tests were performed to determine whether the interaction between treatments and sex of bird, and within sex of bird, had any significance. The data were analyzed by ANOVA using IRRISTAT for Windows version 5.0 [14]. The means were tested by Duncan's new multiple range test at 5% and 1% levels of significance.

Table 1. Composition and nutrient content of starter (d1 to 21) and grower (d22 to 42) basal diets for broiler chicks.

	Starter (0-3 weeks)					Grower (3-6 weeks)				
	YC	PFC (%)				YC	PFC (%)			
Ingredients		**20**	**30**	**40**	**60**		**20**	**30**	**40**	**60**
Maize, %	56.8	40.0	30.0	20.0	-	61.4	40.0	30.0	20.0	-
Purple field corn, %	-	20.0	30.0	40	55.3	0.0	20.0	30.0	40.0	60.0
Soy bean meal, %	36.4	36.6	36.5	36.5	36.6	31.5	31.7	31.5	31.5	31.6
Limestone, %	0.3	0.5	0.7	0.8	0.9	0.0	0.6	0.2	0.3	0.4
DCP, (P18) %	3.1	2.8	2.6	2.4	2.2	3.0	2.6	2.5	2.3	2.0
Palm oil, %	2.8	3.4	3.6	3.9	4.3	3.6	4.0	4.3	4.5	5.0
Salt, %	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Premix, %	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total, %	100	100	100	100	100	100	100	100	100	100
Nutrient content analysis										
-ME, Kcal	3,080	3,080	3,080	3,080	3,080	3,170	3,170	3,170	3,170	3,170
-Protein, %	22.0	22.0	22.0	22.0	22.0	20.0	20.0	20.0	20.0	20.0
-Calcium, %	0.9	0.9	0.9	0.9	0.9	0.85	0.80	0.80	0.80	0.80
-Total phosphorus, %	0,7	0,7	0,7	0,7	0,7	0.65	0.65	0.65	0.65	0.65

Note: YC means = corn grain, PFC = purple field corn grain, DCP = dicalcium phosphase

Figure 1. Purple field corn showing anthocyanins in the kernel from trials conducted at The Purple Field Corn Breeding Program of RMUTL, Phitsanuloke.

Results

The data on dressing percentage, alimentary tract, liver, gizzard, spleen, heart, bursa gland, abdominal fat, winglet (upper wing), wing drumette (lower wing), thigh, shank, breast and breast filet (% of live body weight) are presented in Table 2. The treatments produced results showing highly significant ($P<0.01$) and significant ($P<0.05$) difference in average percentage of heart weight and abdominal fat (Table 2). In summary, the results showed that, up to certain levels, by increasing the ratio of purple field corn, with anthocyanins in the grain, heart weight was decreased. Thirty and forty percent of purple field corn in diets showed efficiency to reduce heart weight of broilers as 0.48 ± 0.01, 0.44 ± 0.03, respectively. The results showed little difference between 20% and 60% purple field corn addition, with heart weights as 0.52 ± 0.02, 0.53 ± 0.01%, respectively. The purple field corn with anthocyanins in the grain was also significant in reducing abdominal fat in broilers. The results showed high potential of purple field corn to decrease heart weight and the percentage of abdominal fat in chickens, more so than yellow corn. The dressing percentage, alimentary tract, liver, spleen, bursa gland, winglet (upper wing), wing drumette (lower wing), thigh, drumstick, shank and breast of chicks fed with purple field corn and yellow corn diets were not different ($P> 0.05$). The analysis of variance showed difference ($P< 0.05$) within sex of bird (male and female broilers) in average percentage of drumstick, thigh, breast fillet, gizzard and was highly significant ($P<0.01$) in shank (Table 3). The male broiler had average percentage of drumstick, thigh and shank more than female broiler. All of the broilers fed with purple field corn had dark purple or almost black feces.

Discussion

The difference ($P< 0.05$) within sex of broiler chicken in average percentage of gizzard, drumstick, breast fillet and highly significant ($P<0.01$) in shank of chicken were similar to Yates *et al*. [15]; Satterlee and Gildersleeve, [16]; Satterlee *et. al*. [17] and Ojedapo *et. al*. [18], who reported that male broiler chicken showed significantly ($P<0.05$) higher values of shank, drumstick, breast fillet and gizzard than female chicken. Romeo-Sanchez *et. al*. [19], suggested that male broiler shank length was longer and thicker than the female because of it could affect the intersexual cloacal distance during mating and struggling behaviour [17].

The highly significant difference in heart weight ($P<0.01$) in broilers fed with purple field corn grain compared with yellow corn was in agreement with Al-Awwadi *et. al*. [20], whose research reported that heart weight of rats fed with an aqueous solution of an anthocyanins grape extract was significantly lower than a diet comprised of water only and a solution containing a vitaflavan polyphenolic grape seed extract group. Shino *et. al* [21] indicated the effects of continuous administration of anthocyanins from purple corn, purple sweet potato and red radish in hypertensive rat diet for 15 weeks, the heart rate of rat administered each treatment decreased as compared to the control group from the early stage of administration. Many research results suggest that plant derived colours such as blueberries, cherries, raspberries, strawberries, black currants, purple grapes, chokeberry, bilberry, elderberry, red cabbage and red wine containing anthocyanins have anti-hypertensive effects on hypertensive animals [22]. Toufektsian *et. al*. [23] used maize kernels to prepare rodent food in which anthocyanins were either present or absent. Male Wistar rats were fed the anthocyanin-rich or the anthocyanin-free diet for 8 weeks. Anthocyanins were significantly absorbed and detected in the blood and urine of only rats fed the anthocyanin-rich diet. The hearts of rats fed the anthocyanin-rich diet were more resistant to regional ischemia and reperfusion insult. Moreover, on an *in vivo* model of coronary occlusion and reperfusion, infarct size was reduced in rats that ate the anthocyanin-rich diet than rats which consumed anthocyanin-free diet ($P<0.01$). However, Toufektsian *et. al*., suggested the cardioprotection was associated

with increased myocardial glutathione levels, so the dietary anthocyanins might modulate cardiac antioxidant defences [23]. The efficacy of purple field corn grain containing anthocyanins for heart health as found in this research concurs with the work on anthocyanins in other plants such as enhanced extracts prepared from chokeberry, bilberry, elderberry having efficacy to produce endothelium-dependent relaxation in porcine coronary arteries. Anthocyanin extracts from *Hibiscus sabdariffa* Linn. showed antioxidant properties for liver defence in rabbits which were treated with 2,4-dinitrophenylhydrazine (2,4-DNPH). The side effects of 2,4-DNPH include tissue lipid peroxidation and depletion of antioxidant defences. *Hibiscus* anthocyanin extract decreased red blood cell counts, but increased white blood cell counts, while on the other hand, anthocyanin extracts from dried calyces of *H. sabdariffa* protected the blood against 2,4-DNPH lipoperoxidative and hemolytic effects in rabbit liver [24].

Table 2. Effect of purple field corn in broiler chicken diets on heart weight, abdominal fat and carcass quality.

Items (%body weight)	Yellow Corn	OPV of Purple Field Corn			
		20%	30%	40%	60%
Initiation ,birds/group	120	120	120	120	120
Male chicks, birds/group	60	60	60	60	60
Female chicks, birds/group	60	60	60	60	60
Heart weight****,** %	0.55±0.01^{a}	0.52±0.02^{b}	0.48±0.01^{c}	0.44±0.03^{d}	0.53±0.01b^{b}
Fat abdominal*, %	1.47±0.03^{a}	1.33±0.10^{bc}	1.36±0.08^{cd}	1.26±0.05^{de}	1.23±0.07^{e}
Dressing percentage^{ns}, %	78.46±0.08	78.28±0.66	78.29±0.32	78.54±0.47	77.34±0.10
Alimentary tract^{ns} , %	12.52±0.02	12.85±0.10	12.47±0.47	12.85±0.19	12.90±0.18
Liver weight^{ns},%	1.96±0.01	2.11±0.17	1.90±0.09	1.94±0.04	1.93±0.07
Spleen weight^{ns}, %	0.11±0.01	0.12±0.01	0.11±0.01	0.13±0.01	0.13±0.01
Gizzard weight^{ns}, %	3.66±0.15	3.67±0.09	3.50±0.19	3.67±0.02	3.67±0.04
Bursa gland^{ns}, %	0.13±0.02	0.13±0.01	0.11±0.03	0.10±0.02	0.11±0.01
Wing^{ns}, %	8.35±0.11	8.23±0.13	7.91±0.22	7.90±0.05	7.97±0.25
Winglet^{ns}, %	4.27±0.01	4.32±0.07	4.03±0.08	4.16±0.01	4.03±0.16
Wing drumette^{ns} , %	3.99±0.07	3.99±0.07	3.72±0.09	3.77±0.01	3.97±0.08
Thigh^{ns} , %	10.92±0.31	11.33±0.21	11.18±0.42	11.41±0.09	11.04±0.04
Drumstick^{ns}, %	10.42±0.17	10.46±0.12	10.08±0.38	10.46±0.01	10.32±0.19
Shank^{ns}, %	3.88±0.22	3.93±0.24	3.58±0.15	3.71±0.09	3.73±0.16
Breast^{ns}, %	16.49±0.38	16.98±0.11	17.06±0.43	16.76±0.05	16.55±1.24
Breast filet^{ns}, %	3.32±0.07	3.44±0.01	3.34±0.11	3.38±0.07	3.42±0.12

Means± SD (n=6),
^{ns}no significant difference (P>0.05),* significant difference (P<0.05),** highly significant difference (P<0.01)
winglet = upper wing, wing drumette =lower wing.

The average percentage of heart weight in broilers fed with 20, 30, 40 and 60% of purple field corn was lower than the yellow corn groups as 0.52±0.02, 0.48±0.01, 0.44±0.03, 0.53±0.01 and 0.55±0.01%body weight, respectively. These values showed the efficacy of anthocyanins in purple field corn grain for heart health because of 60% of purple field corn diet in starter feed and grower feed containing palm oil, 4.3% and 5.0% (Table 1), was higher than 20% purple field corn, 3.4% and 4.0%, and yellow group, 2.8% and 3.6%, respectively. Thus, purple field corn with anthocyanins in grain may have potential to improve heart health because the consumption of dietary fat generally contributes to the elevation of lipids in the blood, which is a major risk factor for atherosclerosis and heart disease [25]. Tsuda *et. al*.,

indicated that anthocyanins from purple corn would not have any activity after ingestion in biological systems because they are unstable under neutral conditions [5]. However, Cyanidin-3-Glucoside or C3G in anthocyanin colour of purple corn has antioxidant activity and suppression of body fat accumulation was not due to inhibition of dietary fat digestion and reduction of energy intake. The effects these pigments cause in the body include prevention of the generation of free radicals, decreased lipid peroxidation, reduced pancreatic swelling and decreased blood sugar concentrations in urine and blood serum [26]**.** Tooru and Takatoshi suggested that purple corn colour at a dose of 7.4 mg/kg anthocyanins in spontaneous hypertensive rats twice a day for 5 weeks significantly inhibited the increase in systolic blood pressure [27].

The main anthocyanin of purple corn is cyanidin-3-glucoside [28]. In vitro, antiradical capacity of purple corn extract against the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical was greater than blueberries (*Vaccinium corymbosum* L., Ericaceae), which have shown higher antioxidant values than many other commercial food plants [6]. The decrease in abdominal fat in purple field corn groups was similar to Tsuda *et al*. [5] who indicated that anthocyanins from purple corn prevented obesity in C57BL/6J mice fed a high-fat diet compared to a high-fat diet with no anthocyanins. Mice fed a high-fat diet containing anthocyanins had decreased serum levels of glucose and insulin. Prior *et. al*., reported that purified anthocyanins from blueberries or strawberries reduced obesity [29]. Mi-Ran *et. al*. [30] found that cyanidin and C3G have the potential to suppress the inflammatory responses of adipose cells and the migration of RAW 264.7 macrophages induced by mesenteric adipose tissue-conditioned medium, so, activation of the cells to produce inflammatory chemokines such as monocyte chemoattractant protein-1 (MCP-1) and macrophage inflammatory protein-related protein-2 (MRP-2) were inhibited. Mi-Ran *et. al*. went further to suggest that cyanidin and C3G may suppress the inflammatory responses of adipose tissue in obesity [30].

The feces of broilers fed with purple field corn having dark purple colour was similar to the findings of Nabae *et. al*. who reported that F344 rats fed with purple corn for 90 days had black feces [31].

Table 3. Influence of within sex of broiler chicken fed with purple field corn on gizzard, breast fillet, thigh drumstick , shank and carcass quality.

Items (%body weight)	Male Broiler chicken	Female Broiler chicken	Statistics	%CV
Dressing percentage, %	78.26±0.58	78.113±0.56	Ns	
Heart weight, %	0.51±0.01	0.49±0.01	Ns	
Bursa gland, %	0.13±0.02	0.11±0.01	Ns	
Abdominal fat, %	1.33±0.12	1.33±0.09	Ns	
Alimentary tract , %	12.69±0.37	12.75±0.15	Ns	
Liver weight,%	1.99±0.14	1.94±0.06	Ns	
Spleen weight, %	0.12±0.01	0.12±0.01	Ns	
Wing, %	8.13±0.27	8.13±0.20	Ns	
Winglet, %	4.14±0.19	4.19±0.08	Ns	
Wing drumette , %	3.87±0.16	3.87±0.09	Ns	
Breast, %	16.47±0.53	17.07±0.53	Ns	
Breast fillet, %	3.33±0.07	3.43±0.05	*	
Gizzard weight, %	3.56±0.12	3.69±0.05	*	
Thigh, %	11.32±0.27	11.04±0.25	*	
Drumstick, %	10.47±0.08	10.22±0.25	*	
Shank, %	3.89±0.18	3.65±0.11	**	

Conclusions

Purple field corn in broiler chicken diets had no affect on carcass quality. Sex of bird had influence on shank, gizzard, breast fillet and drumstick of broilers. The increase of purple field corn in experimental diets was highly significant ($P<0.01$) in decreasing heart weight of broilers. This experiment and previous data of RMUTL researchers confirmed that purple field corn grain with anthocyanins applied as a new feed component in poultry and swine diets in a role similar to that of yellow corn has the potential to benefit heart health.

References

1. Cone, K.C., Burr, F.A. and Burr, B. (1986). Molecular analysis of the maize anthocyanin regulatory locus Cl. **Proceedings of the National Academy of Science**, USA 83: 9631-9635.

2. MacClintock, B. (1984). The significance of responses of the genome to challenge. **Science**, 226:792-801

3. de Pascual-Teresa, S., Santos-Buelga, C. and Rivas-Gonzalo, J.C. (2002). LC-MS analysis of anthocyanins from purple corn cob. **Journal of the Science of Food and Agriculture**, 82(9):1003-1006.

4. Aoki, H., Kuze, N. and Kato, Y. (2000). Anthocyanins isolated from purple corn (*Zea mays*L.) [On-line] Available: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids =11485824&dopt =Abstract

5. Tsuda, T., Horio, F., Uchida, K., Aoki, H. and Osawa, T. (2003). Dietary cyanidin 3-O-ß-D-glucoside-rich purple corn color prevents obesity and ameliorates hyperglycemia in mice. **Journal of Nutrition**, 133:2125-2130.

6. Cevallos-Casals, B.A. and Cisneros-Zevallos, L. (2003). Stoichiometric and kinetic studies of phenolic antioxidants from Andean purple corn and red-fleshed sweet potato. **Agricultural and Food Chemistry**, (11):3313-9

7. Amnueysit, P., Amnueysit, K., Paraksa, N., Attamangkune, S. and Suksombat, W. (2004[a]). Determination of the apparent metabolizable energy of purple field corn in laying hen and broiler chickens. *Kasetsart University Corn and Sorghum Research Program Workshop*. May, Ayuthaya, Thailand, pp 314-322.

8. Amnueysit, P., Amnueysit, K., Paraksa,N., Attamangkune,S. and Suksombat, V. (2004[b]). Purple field corn: new feedstuff. *International Symposium on Animal Production for Food and Environmental Security*. August, Bangkok, Thailand, pp 78-83.

9. Amnueysit, P., Amnueysit, K., Paraksa, N., Attamangkune, S. and Suksombat, V. (2005). Utilization of purple field corn in laying hen diets on performance and egg quality. *Proceedings of the International Conference on Maize Adaptation to Marginal Environments.* March, Nakorn Ratchasima, Thailand, pp 133-139.

10. Amnueysit, K., Amnueysit, P. and Tatakul T. (2007). Nutrient evaluation of new feedstuff, purple field corn, for poultry feed. *International Conference on Bridging Gaps in Agriculture Research and Development Toward Sustainable Development*. April, Nueva Ecija, Philippines.

11. Amnueysit, P., Tatakul, T., Chalermsan, N. and Amnueysit, K. (2008). Determination of Nutritive Value and Metabolizable Energy of New Feedstuff, Purple Field Corn in Growing Pigs. *13th Animal Science Congress of the Asian-Australian Association of Animal Production Societies*. Hanoi, Vietnam, September.

12. Amnueysit, P., Tatakul, T., Chalermsan, N. and Amnueysit, K. (2009). Comparison of Digestibility and Metabolizable Energy of Purple Field Corn between Male and Female Growing Pigs. *1st International Conference on Corn and Sorghum Research*. April, Pattaya, Thailand.

13. NRC. (1994). Nutrient requirements of poultry. 9th Ed. National Academy Press, Washington,D.C.

14. IRRISTAT. (1991). IRRI statistics. Project management services and biometrics. International Rice Research Institute: Los Banos, Philippines.

15. Yates, J. D., C. C. Brunson, and J. E. Webb, (1976). Relationships of certain biochemical, physical, and quality characteristics of broiler muscles. **Poultry Science**, 55:369–378.

16. Satterlee, D.G. and R.P. Gildersleeve (1983). Factors affecting broiler processing parameters and plasma corticosterone. **Poultry Science**, 62:785–792.

17. Satterlee, D.G., Parker, L.H., Castille, S.A., Cadd, G.G. and Jones, R.B. (2000). Struggling Behavior in Shackled Male and Female Broiler Chickens. **Poultry Science**, 79:652–655.

18. Ojedapo L.O., Akinokun, L.O., Adedeji, T.A., Olayeni, T.B., Ameen S.A. and Amao S.R. (2008). Effect of Strain and Sex on Carcass Characteristics of Three Commercial Broilers Reared in Deep Litter System in the Derived Savannah Area of Nigeria. **World Journal of Agricultural Sciences**, 4 (4): 487-491.

19. Romeo-Sanchez, H., Plumstead, P.W., Leksrisoinpong, N. and Brake, J. (2007). Feeding broiler breeder males 2): Effect of cumulative rearing nutrition on body weight, shank length, comb height and fertility. **Poultry Science**, 86:175-181.

20. Al-Awwadi, N. A., Araiz,C., Bornet,A., Delbosc,S., Cistol, J.P. Linck, N., Azay,J., Teissedre,P. and Cros, G. (2005). Extracts Enriched in Different Polyphenolic Families Normalize Increased Cardiac NADPH Oxidase Expression while Having Differential Effects on Insulin Resistance, Hypertension, and Cardiac Hypertrophy in High-Fructose-Fed Rats. **Journal of Agricultural and Food Chemistry**, 53 (1), pp 151–157.

21. Shino, M, Kasa, T., Abe, A. and Kondo, Y. (2007). Effects of dietary administration of plant-derived aAnthocyanin-rich colors to spontaneously hypertensive rats. **Journal of Nutritional Science and Vitaminology**, 53: 90-93.

22. Mazza, G. (2007). Anthocyanins and heart health. Ann Ist Super Sanità 43 (4) : 369-374.

23. Toufektsian, M-C., de Lorgeril, M., Nagy, N., Salen, P., Benedetta Donati, M., Giordano, L., Mock, H.P. Peterek, S., Matros, A., Petroni, K., Pilu, R., Rotilio, D., Tonelli, C., de Leiris, J., Boucher, F. and Martin, C. (2008). Chronic dietary intake of plant-derived anthocyanins protects the rat heart against ischemia-reperfusion injury. **Journal of Nutrition**, 138:747-752.

24. Ologundudu, A., Ologundudu, A. O., Ololade A. and Obi, F.O. (2009). Effect of *Hibiscus sabdariffa* anthocyanins on 2, 4-dinitrophenylhydrazine-induced hematotoxicity in rabbits. **African Journal of Biochemistry Research**, Vol.3 (4), pp. 140-144.

25. Kinsella, J.E., Lokesh, B. and Stone, R.A. (1990). Dietary n-3 polyunsaturated fatty acids and amelioration of cardiovascular disease: possible mechanisms. http://www.faqs.org/abstracts/Health/Dietary-n-3-polyunsaturated-fatty-acids-and-amelioration-of-cardiovascular-disease-possible-mechanis.html

26. Jankowski A, Jankowska B, Niedworok J. (2003). The influence of *Aronia melanocapra* in experimental pancreatitis. **Pol Merkuriusz Lek**, 8(48):395–398.

27. Tooru, K. and Takatoshi, T. (2004). Antihypertensive Activity of purple corn color in spontaneously hypertensive rats. **Food and Food Ingredients Journal of Japan**, 8;671-675,679.

28. Harborne, J.B. (1998). Phenolic Compounds In Phytochemical Methods: a guide to modern techniques of plant analysis. 3rd edition. Chapman & Hall, New York,;pp. 66-74.

29. Prior, R.L., Wu, X., Gu, L., Hager, T.G., Hager, A. and Howard, L.R. (2008). Whole Berries versus Berry Anthocyanins: Interactions with Dietary Fat Levels in the C57BL/6J Mouse Model of Obesity. **Journal of Agricultural and Food Chemistry**, 56 (3): 647–653.

30. Mi-Ran, C., Ji-Hve, K., Hoom, Y., Chae-Ha, Y., Mi-Ok, K., Ri-Na, Y. and Suck-Young, C. (2007). Cyanidin and Cyanidin-3-O-β-D-glucoside Suppress the Inflammatory Responses of Obese Adipose Tissue by Inhibiting the Release of Chemokines MCP-1 and MRP-2. **Journal of Food Science and Nutrition**, 12(3): 148-153.

31. Nabae, K., Hayashi., Kawabe, M., Ichihara, T., Hagiwara, A., Tamano, S. sushima, Y., Uchida, K., Koda, T., Nakamura, M., Ogawa, K. and Shirai, T. (2008). A 90-day oral toxicity study of purple corn color, a natural food colorant, in F344 rats. **Food and Chemical Toxicology**, 46(2): 774-780.