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Feed, Animal and Human Health: Designing Functional Egg

Ali Agus[1,*], Chusnul Hanim[1], Muhsin Al Anas[1], and Agussalim Agussalim[1]

[1]*Department of Animal Nutrition and Feed Science, Faculty of Animal Science, Universitas Gadjah Mada. Jl. Fauna 3 Bulaksumur, Sleman 55281, Yogyakarta, Indonesia.*
[*]*Corresponding author: aliagus@ugm.ac.id*

ABSTRACT
In currently decades, the demand of functional foods is increasing and would increase continuously in the future. Since their roles can decrease of several diseases risk and can increasing the life expectancy. In addition, the consumers expect more and more food especially from animal products that are free from the antibiotics, hormone, additive, *salmonella*, *Escherichia coli*, and GMO. Among food of animal products, eggs are very interesting from the point of view of functionality, because they are as the moderate calorie source, an excellent quality protein, rich in vitamins and minerals, inexpensive and highly nutritious food. The develop of the functional foods from egg-derived by technological methods is interest strategy to enhance profitability of egg producers and food industry and improving public health condition in generally, especially in the developing country such as Indonesia. This paper briefly discusses the roles of functional egg for human health, how to design functional eggs, and to developing small holder cage-free layer farming to produce functional egg.

Keywords: *backyard cage-free layer farming, functional egg, human health,*

1. INTRODUCTION

Currently, foods are also a part of people's lifestyle beside providing nutrients that required by human and also preventive of diseases that related to nutrition and improving mental and physical conditions of consumers. Eggs are very interesting especially from the functionality view point, its contain relatively low energy (around 150 kcal/100 g), an excellent quality protein, versatility of great culinary and affordable [1], which make eggs can be reached by the mostly of the population.

Eggs are highly nutritious and cheap food, containing 18 vitamins and minerals, their composition is influenced by several factors like strain, hen diet, age, and environmental. In addition, eggs rich in compounds of fat-soluble, thus, be a diet nutritious inclusion for people from all ages and at dissimilar life stages. Eggs are roles in human diets at risk of intakes in low nutrient like pregnant women, children, and elderly [2,3]. In addition, consumption of eggs by people from all over the world have not use restricted by religion rule [4].

The quality of egg could be influenced by several factors consists of chain of production, hen laying genetic and age, farming method, status of physiological, feeding strategy, egg postharvest (processing and storage time or conditions) [5–11]. Egg quality based on chemical composition can be developed from the addition of the feed supplement from organic resources or herbals. Eggs can also be improved with antioxidants (i.e., vitamin E, selenium, carotenoids, and iodine) through nutrient and feeding manipulation.

2. NUTRITIONAL VALUE OF EGG

As an essential part of human daily food, eggs are the very good source of quality proteins, lipids, minerals, and vitamins. Proteins present in the egg such as lysozyme, ovalbumin, ovotransferrin, and phosvitin in egg white; while carotenoids, phospholipids in egg lipids and free amino acids in egg yolk and micronutrients like vitamin E and A, carotenoids, and selenium that may have an antioxidant properties. Several antioxidants of lipophilic like vitamin E, selenium, carotenoids, and

iodine can be transferred into egg yolk through feed ingredients to produce eggs rich in antioxidant. Nutritional composition of hen eggs [3] is shown in Table 1.

Table 1. Nutritional composition of hen eggs [3]

Component (unit)	Amount	Component (unit)	Amount
Egg shell (%)	10.5	Ca (mg)	56.0
Egg yolk (%)	31.0	Mg (mg)	12.0
Egg white (%)	58.5	Fe (mg)	2.1
Moisture (g)	74.5	P (µg)	180.0
Energy (Kcal)	162	Zn (mg)	1.44
Protein (g)	12.1	K	147.0
Carbohydrates (g)	0.68	Thiamine (mg)	0.09
Lipids (g)	12.1	Riboflavin (mg)	0.3
SAFA (g)	3.3	Niacin (mg)	0.1
MUFA (g)	4.9	Folic acid (µg)	65.0
PUFA (g)	1.8	Cyanocobalamin (µg)	66.0
Cholesterol (mg)	410	Pyridoxine (mg)	0.12
Iodine (µg)	12.7	Retinol equivalents (µg)	227.0
Tocopherols (µg)	1.93	Carotenoids	10.0
Selenium (µg)	10.0	Cholecalciferol (µg)	1.8

Represent an edible portion for 100 g; SAFA: Saturated fatty acids MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids

Albumen in the egg contains much more functional protein that consists of macro and micro proteins. The macro proteins are ovalbumin (54%), ovo-transferrin (12%), ovomucoid (11%), ovoglobulin (8%), lysozyme (3.5%), and ovomucin (3.5%). Furthermore, the micro proteins are ovoinhibitors, ovomacroglobulin, ovoglycoprotein, ovo-flavoprotein, thiamine-binding protein, and avidin and each from them have the role in human health [3,5]. Ovalbumin is the source of antioxidant, and their hydrolysate play a role as the stronger angiotensin converting enzyme (ACE) inhibitor to decrease the hypertension.

Ovotransferrin, ovomucin, and lysozyme have role as an antimicrobial and ovomucoid is known has the activity trypsin-inhibitor that its role as an anticancer and to normalize the insulin production in diabetes mellitus. Ovomucin has a role as an antimicrobial, antiviral, antitumor, and decrease the cholesterol absorption. In addition, ovomacroglobulin, avidin, ovoglycoprotein, ovoglobulin, ovoinhibitors, ovoflavoprotein, thiamine-binding protein, and ficin/papain contain peptide that play a dominant role as the antioxidant and antimicrobial [3,5]. Albumen contains amino acids and peptide that role in enzyme and hormone production, component to formed DNA, tissue, and growth, body metabolism. In the body, the albumen is the high adsorb for 94% [4].

Ovotransferrin include glycoprotein of monomeric consist of 686 amino acids and their molecular weight is 77.9 kDa with isoelectric point is 6.0 [1,2] and include in family of glycoproteins of binding iron transferrin. In addition, as the soluble glycoprotein from the family of transferrin protein present in avian with their composition 12-13% of proteins total from egg white. Ovotransferrin is present both in avian plasma and egg white and have both protective and iron-transfer properties [12] that contributing to promotes the growth and development from the chicken embryo especially to prevent the micro-organisms growth together with other proteins like lysozyme [3], cystatin [13,14], ovomacroglobulin [15] and avidin [16].

In addition, egg white is contains ovoinhibitor that roles as an inhibitor a serine proteinase that can lessen digestion of enzymatic by trypsin and chymotrypsin, and also has been proven that certain proteins of egg can be absorbed whole [17–19]. Lysozyme can be absorbed whole by transport of endocytic and paracellular in rats proximal intestine [18], while ovalbumin can be adsorbed in the intestine of distal through paracellular and endocytic transport that mediated by receptor and clatharin [19]. The absorption of whole egg proteins has been contributed in mediating responses of allergic to egg proteins and heating process and digestion proteins of egg can decreased allergenicity [18–20]. Methods for preparation and cooking of eggs may be influencing the bioavailability of egg proteins for overall and the studied of egg protein that cooked is showed that they are highly digestible (91%) than raw egg protein (51%) [21].

Yolk is relatively rich in cholesterol. Consumers perception about egg yolk has been so far negative for the human health. However, cholesterol is also the nutrient source required by the body to form cells wall. Egg yolks contain omega-3 including long chain fatty acid such as PUFA group. Omega-3 in yolk consists of alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). The EPA and DHA components play the role to decrease the cardiovascular risk, nervous system disorders, mental disorders, inflammatory, infection in immune system, and to prevent from chronic disease. DHA is more effective to prevent the cardiovascular risk and used to developing brain tissue, retina, and nervous in embryo and children [3,5,22]. In addition, yolk also contain immunoglobulin-Y (Ig-Y) in which their compounds have important role as an antibody and their concentration is 10-20 mg/mL. Ig-Y has roles to inhibit the pathogen bacterial growth such as *Salmonella*, *Helicobacter*, and *Streptococcus* and as an antiviral for influenza [5,23,24].

3. EGG CONSUMPTION AND HUMAN HEALTH ISSUE

For many years (±50 years), eggs and dietary cholesterol are accused contributing to high levels of plasma cholesterol and increasing the risk of cardiovascular disease. Since 1968, the American Heart Association has been recommendation that the daily

consumption of dietary cholesterol is maximum 300 mg/day and 3 eggs/week should be eaten by the sick and healthy individuals. These recommendations without considering that eggs contain essential nutrients for human health and their bioactive components can protection from chronic disease. Only from 2015, in the Food Guide for Americans considered epidemiological information and clinical trial data and therefore finally is eliminating cholesterol intake limits because of the evidence is lacking on the association among dietary cholesterol and heart disease risk.

Eggs are protein source of high quality that can be promote synthesis of protein and to maintain mass of skeletal muscle [25–27]. Eggs known as the functional foods because of their bioactive components may prevent chronic and infectious diseases [3]. Furthermore, eggs also known as an antioxidant, antimicrobial, anticancer and hypotensive properties. One of the bioactive component from egg is phospholipids [13]. Absorption of cholesterol and inflammation are regulated by Sphingomyelin and phosphatidyl choline. In addition, the merger phospholipids of egg into high density lipoprotein (HDL) seem to be the main factor of their capacity to receive cholesterol from the lipoprotein [13]. One of the egg protein is ovotransferrin and their peptides are known as an antioxidant, antibacterial, antiviral activity, and anti-inflammatory properties [14]. Furthermore, proteins of egg yolk like lipovitellin, phosvitin, and vitellogenin are roles in immune defense system, killing bacteria capable and viruses and also to promote activity of phagocytosis [15]. The study in rats showed also that albumin can be used for anemia recovery [16]. These egg proteins may have the role to protect from bacterial infection, and indicated the existence link between egg consumption and health [14–16].

Study on the eggs role as the diet component on the healthy eating index (HEI) have been evaluated from 139 obese Mexican American women postpartum [29]. Results of this study showed that eaters of egg is higher in HEI scores, especially for the higher consumption protein of high quality [29]. Furthermore, the properties of anti-inflammatory from eggs have also been studied by other researcher [30]. The components that play this role are phospholipids, carotenoids, zeaxanthin, lutein, and egg proteins. In addition, also role as an antioxidant and participate in immune defence system was reported [1].

In addition, ovotransferrin known an antibacterial and antiviral properties that protective roles are similar with mammalian lactoferrin. For protective functions from Ovotransferrin on antibacterial activity is related to their ability of binding iron (Fe^{3+}) and consequently it may limit the bacterial growth [23,24]. These functions exhibited by the derived of peptides from ovotransferrin partial hydrolysis that showed the direct relation among the consumption of egg and human health.

Several studies showed that the functional eggs can improve the human health such as functional eggs as an antiinflammation, cardiovascular disease risk, increased HDL, and regulate cholesterol metabolism, heart disease, high blood pressure, diabetes mellitus, cholesterol, uric acid, arthritis, cancer, obesity, and immunomodulator [3,13,31]. Furthermore, one egg consumption per day compared with oatmeal in the breakfast from patients of diabetes mellitus (DM) type-2 showed the unchanged in plasma glucose, proinflammation interleukin-6 (IL-6), and tumor necrosis factor-α (TNF-α), triglycerides, LDL-C, VLDL, IDL or small LDL. In addition, both bioactives lutein and zeaxanthin decreased inflammation in DM type-2 subjects if compared to oatmeal consumption [4].

4. DESIGNING FUNCTIONAL EGG

Functional egg is the eggs have the nutrients property or chemical composition are the best or higher than ordinary eggs. These nutrients usually are bioactive compounds that role to increase the human health or disease prevent. The completed nutrients composition contains in eggs is the key point for functional egg. Functional eggs had the best physical properties than ordinary eggs such as the exterior and interior, whereas the functional eggs have a significant higher consists of height and wide albumens, height and colour of yolks, and haugh unit [5].

Several ways to produce functional egg such as inducing the metabolic changes in the hen, change the characteristic of membrane transport, and feed manipulate. Egg nutrients that can be manipulated such as cholesterol content, fatty acid profile (omega-3 and omegra-6), vitamins (E, D), folic acid, minerals (Fe, Zn, Se, I, and Cr), carotenoids, lutein, and yolk colour. Egg quality based on chemical composition can be developed from the addition of the feed supplement from organic resources [5].

Feed is the essential required by animal to increase productivity and produce a good or healthy animal products such meat, eggs, and milk. However, the good or healthy animal products can be made by feed modification such as organic or multifunctional feed additive formulation or supplementation for poultry especially layer. In layer, quality of egg is one of very important parameters to determine the successfully in farming

The recent study by Zotte et al. that the different methods for farming laying hen (organic, barn, and cage) and when marketed, the organic eggs the most distinguishable than other eggs. They are showed the peculiar physicochemical properties, such as moisture, protein, lipids, ash, yolk colour intensity, physical

properties of eggs (exterior and interior), and profile of fatty acids. In addition, eggs from cage and barn systems showed the similar characteristics. However, the organic eggs have the quality of most relatively constant, especially for physical properties, while both cage and barn eggs have a more variability [10].

5. PRODUCING FUNCTIONAL EGG

Egg nutrient quality and composition are influenced by among other feeding and nutrition. Authors have been developing a multifunctional feed additive (MFA) formula to produce functional egg (happy chicken egg). MFA consist of mineral mix, vitamins, probiotic, herbs extract and the essential oils combination that called Agromix® [5]. Essential oils in chicken are plays as an immunostimulatory, antimicrobial, and increasing the performance of digestive tract so the feed nutrient can be adsorbed optimally.

In addition, the uses of herbal plants such turmeric (*Curcuma longa*), tulsi (*Ocimum tenuiflorum*), amla (*Phyllanthus emblica*), and Aloe vera (*Aloe barbadensis*) in the broiler feed could be increased the feed efficiency, body weight gain, liver and spleen weight, and whole giblet weights. Furthermore, decreased feed intake, mortality rates, and feed cost ranged from 6.2-13.5% and reduced fat accumulation [32]. *Moringa oleifera* (Lam.) pod meal has been used as the layer feed might increase bioactive compounds like β-carotene, quercetin, and yolk selenium levels and decreased cholesterol levels in egg yolk and serum [33].

Haugh unit is an overall the assessment for eggs quality. The heigh and wide of albumen are greater is indicate that the volume of albumen from functional eggs is higher than the ordinary eggs. We have done the trial in laying hens by adding MFA in the feed on the quality of egg (Table 2).

Table 2. The quality of exterior and interior of happy chicken egg (HCE) and ordinary eggs (OE) [5].

Parameters	OE	HCE
Albumen height (cm)	0.60[a]	0.73[b]
Liquid albumen wide (cm)	10.83[a]	11.30[b]
Viscous albumen wide (cm)	8.63	8.64
Yolk height (cm)	1.72[a]	1.82[b]
Yolk wide (cm)	4.17	4.15
Yolk color	4.61[a]	10.12[b]
Thick shell (cm)	0.37	0.36
Shell mass (g)	7.48	7.44
Haugh unit	77.27[a]	84.02[b]

[a,b]Significant at $p<0.05$; HCE: happy chicken egg; OE: ordinary egg

The different among albumen and yolk from functional and ordinary eggs is shown in Figure 1. By adding 0.5% Agromix® in the feed resulted egg with higher albumen protein 12% than control / ordinary egg (21.7% vs 19.4%) (Table 3) [5]. In addition, the cholesterol content of functional is 45% lower than ordinary egg (403.3 vs 616.2 mg/100 g) [34].

Figure 1. An example picture of ordinary (left) and functional eggs (right)

Figure 1 show that the utilization of Agromix® as the multifunctional feed additive have a good impact on the increasing of yolk colour and proportion of albumen in functional egg compared to the ordinary one. The yolk colour from the functional egg is more orange and it related to the pigment of colour much better than ordinary egg. In addition, the pigment colour in yolk has its role as the antioxidant to decrease the oxidative reaction [3,5].

The development of functional egg and their possible derived products can be an excellent strategy for increasing added value of the products and to offer more profit to the egg producers [3]. The small holder cage-free layer farming to produce functional egg has been developed by feed modification using Agromix® as the multifunctional feed additive to produce that the authors called it as a 'happy chicken egg (HCE)'. Its chemical composition compared to the ordinary egg (OE) [5] is shown in Table 3. Producing HCE may be adopted by the small holder farmer by using the Agromix® at 0.5% in the feed as feed supplement, while chicken is raised cage free or free range.

Table 3. The comparison of chemical composition from HCE and OE

Components	HCE	OE	HCE-OE
Protein (g/100 g)	21.7	19.4	+12%
Fat (g/100 g)	6.2	8.8	-30%
Cholesterol (mg/100 g)	806.6	1232.4	-35%
Omega 3 (g/100 g fat)	8.7	8.6	+2%
Omega 9 (g/100 g fat)	2.6	2.3	+16%
Salmonella	Negative	-	-
E. colly	Negative	-	-
Zinc (ppm)	18.3	-	-

Results of analysis from LPPT UGM; HCE (happy chicken egg); OE (ordinary egg)

Data obtained by author's trial [5] indicated that the happy chicken egg has high in protein, omega 9 and low in fat content, and cholesterol than ordinary egg (Table 3). In addition, the analysis of microbes such as *Salmonella* and *E. colly* are not detected in the functional

egg. Multifunctional feed additive consisting of several ingredients or active substances mixture, required essentially by the animal for better health and optimal production (trace mineral, vitamin, amino acid, probiotic, prebiotic, phyto-biotic, and essential fatty acids seem to have the positive role. Roles of multifunctional feed additive such as source of macro mineral and trace minerals, source of vitamins, antioxidant, immuno-stimulator, and balance microbe in the gut [5,34]. The small holder cage-free layer may offer the more freedom of layer to exercise, consume feed according to their requirement, to provide a comfort for the chicken to produce eggs, and respect the animal welfare. In addition, some herbs present in the feed may also increase the chicken health, productivity and egg quality [5]. The cost to produce functional egg is higher than ordinary egg, but the egg quality from functional egg is much better for human health than ordinary egg. Results from previous studies reported that the functional eggs could be used as the functional food to improve the human health such as heart disease, high blood pressure, diabetes mellitus, cholesterol, uric acid, arthritis, cancer, obesity, and immunomodulator [3,31]

The functional egg has been used as the functional food for pregnant women has been studied by Agus et al. (2018-2020) in Sleman Regency, Yogyakarta Special Region Province, Indonesia through program called *Pecah Ranting*. Two HCE are given to 100 pregnant women in condition of chronic energy deficiency for daily consumption (morning and evening) during 90 days. This preliminary study showed that the HCE consumption decrease stunting of the new born and improve 60% pregnant women from chronic energy deficiency. By consuming 2 HEC daily for 90 days, the mother give birth 62% normal new born, while 38% are still under stunting conditions [5]. This stunting case is the high category because the WHO target for stunting value is under 20% [5] where the stunting case in Indonesia around 30.8% [35].

6. CONCLUSIONS

Consuming a good food (functional) is highly recommended for the health. Egg is one of the nutritious food available at affordable price and could be enriched by certain nutrient trough feeding strategies. Designing egg with nutrient promoting health would be an interesting approach. Designer eggs are not only nutritious and tasty, but also promote an overall health of the consumers. Production of designer eggs need suitable technology and expertise. Since, the cost of production will be certainly higher than the ordinary table eggs, the producer should ascertain market before going for this business. Functional egg can be obtained easily by raising a cage-free laying hens with the backyard farming system that may produce better egg quality for better human health. The egg produced might also an excellent quality food for consumer health.

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