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

A Review of the Uses of Poultry Eggshells and Shell Membranes

A.M. King'ori

Department of Animal Sciences, Egerton University, P.O. Box, 536-20115, Egerton, Kenya

Abstract: This study was conducted to find out the multiple uses of eggshells in nutrition and medicine. Eggshells can be utilized for various purposes that minimize their effect on environmental pollution. Eggshells present healthy, balanced calcium due to its trace amounts of other minerals and is probably the best natural source of calcium. One whole medium sized eggshell makes about one teaspoon of powder, which yields about 750-800 mgs of elemental calcium plus other micro elements. Eggshell powder has been reported to increase bone mineral density in people and animals with osteoporosis. In laying hens in the late production phase, eggshell powder has been found to increase egg production and improve the quality of shells. Discarded eggshells are often used as a plant fertilizer and are effective liming sources. This is because eggshells contain calcium that raises, or neutralizes, the pH level of overly acidic soil. Chicken eggshells can be used as an alternative soil stabilizer like lime since they have the same chemical composition. Such stabilized soil can be used as subgrade materials in road construction works. Eggshell membrane consists of collagen as a component. Collagen is a type of protein, fibrous in nature that connects and supports other bodily tissues, such as skin, bone, tendons, muscles and cartilage. Collagen has been isolated mainly from bovine and swine skins and bones. Collagen used in medicine, biochemical, pharmaceutical, food and cosmetics industries. After the outbreaks of bovine spongiform encephalopathy, foot and mouth disease, autoimmune and allergic reactions, restrictions on collagen uses from these sources were enforced. Eggshell membrane collagen is very low in autoimmune and allergic reactions as well as high in bio-safety and is of similar characteristics to other mammalian collagen. Eggshells/shell membranes have multiple uses in nutrition, medicine, construction and art works.

Key words: Poultry eggshells, shell membranes, collagen, gelatin, calcium carbonate, soil stabilization

INTRODUCTION

Eggshells are waste materials from hatcheries, homes and fast food industries (Phil and Zhihong, 2009; Amu *et al.*, 2005) and can be readily collected in plenty. Eggshell waste disposal contributes to environmental pollution. Challenges associated with disposal of eggshells include cost, availability of disposal sites, odour, flies and abrasiveness (Phil and Zhihong, 2009). However, they can be processed into saleable products like fertilizer, used in artwork, human and animal nutrition and building materials and to produce collagen from the membranes (Phil and Zhihong, 2009; Amu *et al.*, 2005). Shell membranes consist of collagen as a component. The collagen is extracted and has diverse uses in medicine, biochemical, pharmaceutical, food and cosmetics industries. These uses minimize their effect on environmental pollution. The eggshell and shell membranes make up 10.2% of the whole egg. The eggshell comprises of calcified shell and shell membranes including inner and outer membranes. MacNeil (1997) developed a patent for separating egg shell membranes from the eggshell. The organic matter of eggshell and shell membranes contains proteins as major constituents with small amounts as carbohydrates and lipids (Burley and Vadehra, 1989). The composition of the egg shell is approximately 98.2,

0.9, 0.9% Calcium carbonate, Magnesium and Phosphorous (phosphate) respectively (Romanoff and Romanoff, 1949). Shell membranes comprises of 69.2% protein, 2.7% fat, 1.5% moisture and 27.2% ash (MacNeil, 1997). Shell membranes protein comprises of approximately 10% collagen (Froning, 1998). Eggshell and shell membranes are non-edible by-products with little saleable value but they may contain biologically active compounds (Nakano *et al.*, 2003).

Uses of eggshells: Eggshells contain calcium and trace amounts of other micro elements, i.e. magnesium, boron, copper, iron, manganese, molybdenum, sulphur, silicon and zinc (Bee, 2011). Eggshell calcium is probably the best natural source of calcium and it is about 90% absorbable (Bee, 2011). It is a much better source of calcium than limestone or coral sources. To make eggshell powder, boil eggshells in hot water for 5-10 min to kill pathogens, then air dry them. Grind them into a fine powder. One whole medium sized eggshell makes about one teaspoon of powder, which yields about 750-800 mgs of elemental calcium (Bee, 2011). The composition of an eggshell is very similar to that of our bones and teeth. It is recommended that people with osteoporosis take 400-500 mg calcium per day to supplement dietary sources. The powder should be

taken together with some added magnesium, zinc, vitamin D3, K1, K2, strontium and boron for efficient utilization. Schaafsma *et al.* (2002) reported a highly positive effect of eggshell calcium supplementation (with added magnesium and vitamin D) on Bone Mineral Density (BMD). In this study, the eggshell supplemented group had measurable increases in bone density in their hip bones, after one year. The findings indicate that healthy late post-menopausal women with an adequate Calcium intake at baseline may increase bone mineral density of the hip within 12 months following supplementation with the chicken eggshell powder-enriched supplement.

Manganese and zinc are involved in egg shell formation and enzymatic activity at uterus level where calcification begins. Zinc as organic form is associated with the increased activity of carbonic anhydrase, improving the quality of egg shell and the presence of manganese has an activator influence on the calcification and resistance of the egg shell (Ceylan and Scheideler, 1999). Extrusion technology has been used to utilize eggshells in laying rations (Froning and Bergquist, 1990). In laying hens feeding, organic sources of micro elements are frequently used. They seem to have a higher biological activity and bioavailability in the hen compared to inorganic sources. Lara *et al.* (2007) reported that offering an organic mineral supplement (Eggshell - 49) to hybrid laying hens between 49-69 weeks of age had favorable effects on the main production indices and quality of egg shells. This was attributed to the role and contribution of the micro elements (manganese, zinc) and macroelements (calcium, phosphorus) present in the Eggshell - 49 supplement in the formation and improvement of the egg shell quality. Similar findings were reported by Gomez (1998); Ceylan and Scheideler (1999). In Japan, researchers studied a combination of vitamin D3 and eggshell powder in animals with osteoporosis. The eggshell powder with vitamin D3 was able to improve bone mineral density without significantly increasing blood calcium levels. Any kind of eggshells (chicken, goose and duck) can be used, but it is best to use shells from birds that get balanced minerals in the diet.

Discarded eggshells are often used as a plant fertilizer. This is because eggshells contain calcium. Making eggshell fertilizer is inexpensive and environmental-friendly, since the process reuses material to promote plant growth. Ground eggshells are effective liming sources (John and Paul, 2006). Calcium raises, or neutralizes, the pH level of overly acidic soil. Most plants prefer slightly acidic soil with a pH between 5.8 and 7.0. A study revealed that red clover plants fertilized with eggshells grew at an average of more than 10 mm larger than plants without eggshells (Planting Science.org, 2011). Sanitized eggshells can be used to increase mineral content of compost and spread around

plants to deter slugs and snails. They are also used by artists to make mosaics and to make textured paint for 3D effects in artwork (Phil and Zhihong, 2009).

The use of soil stabilizer agents like lime and bitumen are expensive and therefore require an economic replacement (Amu and Salami, 2010). Soil stabilization may be broadly defined as the alteration or preservation of one or more soil properties to improve the engineering characteristics and performance. When the mechanical stability of soil cannot be obtained by combing materials, it is advisable to stabilize it by adding lime, cement, bituminous materials or special additives. Chicken eggshells are waste material that can be used as an alternative soil stabilizer like lime since they have the same chemical composition (Amu *et al.*, 2005). However, eggshell powder has not been used as a stabilizing material in most parts of the world but it could be a replacement for other types of stabilization (Olawejaju *et al.*, 2011). Most industrial activities lead to depletion of natural resources and in the process may result in accumulation of by-products and waste materials that may be a problem to dispose. Eggshells are waste materials from hatcheries, homes and fast food industries (Phil and Zhihong, 2009; Amu *et al.*, 2005) and disposal contributes to environmental pollution. The composition of the egg shell is approximately 98.2, % Calcium carbonate, making it a good soil amendment material. Amu *et al.* (2005) reported that eggshells can be an alternative to lime as a soil stabilizing agent while Amu and Salami (2010) in the search for alternative soil stabilizing agents, reported that pulverized eggshells improved the plastic indices of lateritic soil samples. Eggshell powder mixed with lateritic soil possesses low binding properties but can be mixed to significantly improve the strength of soil to be used as a subgrade where very high performance is not necessary (Olawejaju *et al.*, 2011). Eggshell powder capacity as a stabilizer does not meet the minimum requirement for use as base and subbase materials for road construction (Olawejaju *et al.*, 2011). Therefore, pulverized eggshells have potential as a soil stabilizing agent. Such stabilized soil can be used as subgrade materials in road construction works. Pulverized eggshells can be used as an alternative for sand in making hollow blocks because they contain Calcium Carbonate that gives them hardness and strength (Cecilia *et al.*, 2008). To compare the effectiveness of pulverized eggshells and sand in making hollow blocks, a dry block from each mixture was dropped from a height of 2 feet. It was observed that the eggshell block got a crack while the sand block broke into pieces (Cecilia *et al.*, 2008). This indicates that eggshells are more effective than sand. Therefore, use of eggshells can be used to reduce building expenses as well as reduce environmental pollution by recycling them.

Uses of shell membranes: The presence of hydroxyproline in hydrolysates of membrane layers of eggshell membrane has been confirmed by biochemical and immunological tests to consist of collagen (Wong *et al.*, 1984). They primarily consist of type I, V and X collagen (Wong *et al.*, 1984; Arias *et al.*, 1992). All the three kinds of collagen can be used in various fields. Collagen is a type of protein, fibrous in nature that connects and supports other bodily tissues, such as skin, bone, tendons, muscles and cartilage. It also supports the internal organs and is even present in teeth. There are more than 25 types of collagens that naturally occur in the body (Madison, 2011). Collagen is one of the most plentiful proteins present in the bodies of mammals, including humans. It makes about 25 percent of the total amount of proteins in the body. Collagen possesses great tensile strength and functions in a manner that is very different from many other types of proteins. Collagen can be found both inside and outside of cells and fibers are important in contributing to the external structure of cells. However, they are present on the inside of some cells also.

Advances in biotechnology have led to new and quite revolutionary uses of collagen in both medicine and industry (Jamie, 2009). Collagens are widely and diversely used in cosmetics, biochemical and pharmaceutical industries (Ogawa *et al.*, 2004). Collagen used has been isolated mainly from bovine and swine skins and bones. After the outbreaks of bovine spongiform encephalopathy (mad cow disease), foot and mouth disease, autoimmune and allergic reactions, restrictions on collagen trade from these sources were enforced. Therefore, safe alternative sources had to be explored (Devore *et al.*, 2004). Eggshell membrane collagen has been proven to be very low in autoimmune and allergic reactions as well as high in bio-safety (Long *et al.*, 2004). It is of similar characteristics to other mammalian collagen (Yu-Hong and Yu-Jie, 2009) and is therefore an alternative for commercial applications in functional foods, cosmetics, biochemical and pharmaceutical industries (Yu-Hong and Yu-Jie, 2009). Eggshell membrane collagen is extracted by acid-pepsin digestion and isolated by salt precipitation (Yu-Hong and Yu-Jie, 2009).

Collagen works hand-in-hand with elastin in supporting the body's tissues. Basically, it gives body tissues form and provides firmness and strength; elastin gives the same body tissues much need flexibility. This combination of collagen and elastin is very important in many parts of the body, including, but not limited to, the lungs, bones and tendons (Madison, 2011). Even the blood vessels rely on both collagen and elastin. Pilot clinical studies were conducted to evaluate the safety and efficacy of natural eggshell membrane as a treatment for pain and inflexibility associated with joint and connective tissue disorders. It was reported that

supplementation with 500 mg/d of natural eggshell membrane for eight weeks produced a significant reduction in pain and stiffness and improvement for function. This was attributed to the effect of collagen, glucosamine, chondroitin and hyaluronic acid in the eggshell membrane (Ruff *et al.*, 2009). In medicine collagen is commercially sold as a joint mobility supplement.

In the food industry, most of the applications that collagen has is because when it is partly hydrolyzed, it produces gelatin, which is a highly useful especially for flavoring foods (Jamie, 2009). Gelatin has been used in the food industry as a thickening, emulsifying and jelling agent. Nutritionally, both collagen and gelatin are of low protein quality; although some of the collagen based dietary supplements do improve quality of skin and finger nails (Meier, 2006). Skin is made of collagen and as we age, collagen production drops off and skin sags because it gets thinner, weaker, drier and less resilient, or pliable. This deterioration is directly linked to amino acid content. Specific amino acids in the skin's structure, like glycine, proline, hydroxyproline and alanine decrease with age and bad diet.

Collagen and health benefits associated with it have led to establishment of collagen-supplements industry. These collagen supplements are meant to mainly improve the skin appearance of their users and today's being the image-obsessed society, anything offering this particular promise is likely to be in high demand (Jamie, 2009). In 2008, a study in Tokyo with 33 women between 40-60 years old who took 10 g of hydrolyzed collagen daily for 2 months showed a 91% increase in skin hydration and resilience. Similarly, a study in France in 2008 with women 35-55 years old, showed 41% less furrowing, less wrinkles, more resilient and more hydrated skin after 12 weeks of 10g hydrolyzed collagen daily. The skin smoothness and hydration, was measured using the new Corneometer and Skin Image Analyzer technologies while Skin resilience was measured by the ciliary and zonules (C and Z) Cutometer. Metabolites of hydrolyzed collagen build bone, skin and ligaments by attracting fibroblasts that trigger the synthesis of new collagen (Posstlethwaite *et al.*, 1978). Hydrolyzed collagen also increases the diameter of collagen fibrils in the dermis by the same mechanism of fibroblast stimulation. This in turn increases cohesion of the dermal collagen fibers themselves. This action means increased thickness, suppleness and resilience, as well as hydration. Hydration, or water content of skin tissue, is proven to be directly related to overall smoothness and decreased furrowing and wrinkling (Sumida and Hirota, 2004).

Another area that is increasing worldwide demand for hydrolyzed collagen is the field of sports nutrition. Collagen can quickly boost lean muscle gain, decrease recovery time, rebuild damaged joint structures without

surgery and improve cardiovascular performance on athletes. This is accomplished by collagen's promotion of natural creatine, an essential amino acid in new muscle growth following workouts. Arginine within the hydrolyzed collagen also promotes increased muscle mass. Therefore, performing athletes and bodybuilders find hydrolyzed collagen a clean source of collagen protein for lean muscle gain, tendon and ligament repair, fast recovery time and optimum performance.

In cancer patients, as cancer progresses, it often destroys muscle tissue in a very aggressive fashion. The muscles of the arms and legs seem to turn to limp string, a condition referred to as cachexia. When cancer patients use hydrolyzed collagen, a wide range of clinical gains are demonstrated. First chronic arthritis conditions, especially of shoulders and knees that had been weak and painful, they become normal. For many patients the skin thickens and tightens, soon after daily supplementation begins and hair commonly thickens as well. There is dramatic improvement in liver problems, prostate problems, lung deficits and heart problems, especially blood pressure with daily collagen doses. When the physiology of these conditions is considered, the body is being provided with the building blocks of its own new collagen and therefore it prioritizes where the collagen is needed most.

The oldest glue ever used, dated some 8000 years back was collagen. Collagen is applied to hold utensils and is also very useful for musical instruments like the violin and guitars which have to be opened frequently for repairs. Collagen on reheating can be softened easily unlike the synthetic plastic adhesives which are permanent. Collagen is used for cosmetic and burns surgery (Meier, 2006; Jamie, 2009). Collagen is good for construction of artificial skin substitutes for skin burns and may be used with a mixture of fibroblasts, growth factors, silicone and glycosaminoglycans. Before this particular application of collagen became possible, it was impossible to restore cosmetic appeal of fire victims. They had to live the rest of their lives with the absolute disfigurement a fire accident can cause and the social disadvantage such disfigurement can mean (Jamie, 2009). They would live with emotional pain from the fire, long after the physical pain from the same had healed. Through the use of collagen, it is possible to produce quite impressive results with reconstructive plastic surgery on former fire accident victims. Sometimes the results make it impossible to know that the victims had ever been involved in such an incident (Jamie, 2009). Collagen is a good medical aid in orthopedics and dentistry, where it is widely used as a treatment aid, making possible procedures that were absolutely impossible or even unthinkable before the advent of its use (Jamie, 2009). Collagen is also used in the manufacture photography aids (especially the variety that dominated before the advent of digital photography).

Conclusion: Eggshells/shell membranes have multiple uses as:

- A fertilizer supplying calcium and an amendment for acidic soils.
- A remedy for osteoporosis and joint motility ailments.
- A soil stabilizer for use as construction materials.
- A calcium supplement for hybrid layers in the late production phase that increases egg production and improves shell quality.
- In artwork for production of mosaics and as glue in musical instruments.
- In cosmetics and burn surgery where it improves skin appearance (plastic surgery).
- In orthopedics and dentistry as a treatment aid.
- In the treatment of cancer patients to boost muscle gain and hair thickening
- In sports nutrition to increase performance on athletes
- In food industry as a food flavour.
- In photography for production of photography aids.

Implications: Eggshells from the hatcheries, fast food industries and homes should not be disposed in a way that pollutes the environment. In developing countries, the communities should be sensitized on the many uses of eggshells/shell membranes. Research should be carried out to customize their utilization based on locally developed technologies. Where the quantities generated are not economical, the communities should be encouraged to deliver them at collection points for onward delivery to a central point where they can be processed into the various products. This will create employment, increase returns from poultry production, make the products locally available presumably at lower cost and minimize environmental pollution.

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