INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)

ISSN: 2223-7054 (Print) 2225-3610 (Online)

http://www.innspub.net

Vol. 19, No. 5, p. 60-73, 2021

REVIEW PAPER

OPEN ACCESS

Quail (*Coturnix japonica*) eggs composition, properties and processing for preservation: A review

Ekpo Kotchikpa Justin[*1,3], Diantom Agoura Joseph[2], Glago Jean[1], Osseyi Elolo Germain[2], Dossou Joseph[3], Karou D. Simplice[2]

[1]*Regional Center of Excellence in Poultry Sciences (CERSA), University of Lome (UL), Lome, Togo*

[2]*College of Biological and Food Techniques (ESTBA), University of Lome, Lome, Togo*

[3]*Laboratory of Bioengineering of Food Processes (LABIOPA), Faculty of Agronomic Sciences (FSA), University of Abomey, Calavi, Cotonou, Benin*

Article published on November 30, 2021

Key words: Quail eggs, Nutrients, Enzyme, Processing technology, Therapeutic values

Abstract

This review focused on the preservation, processing and properties of Japanese quail (*Coturnix japonica*) eggs. Despite its nutritional richness and therapeutic virtues, this valuable product is still unknown to many people and the loss of quail eggs production remains high due to the lack of preservation in some parts of Africa, including Benin. This study examined the available data on the uses, qualities and processing technologies of quail eggs. The reviewed literatures revealed that Japanese quail eggs are richer in nutrients, compared to the eggs of other poultry species. It has also been established that quail eggs possess physico-chemical, nutritional, functional and inhibitory characteristics. It should also be noted that the therapeutic values of quail eggs are mainly associated with their ability to inhibit serine proteases such as trypsin, elastase and others. Quail eggs can act as nutraceuticals by preventing, relieving and curing several diseases, including allergies. Although quail eggs are often consumed as a complete food, they can also be processed into egg products using various technologies such as freeze-drying, pasteurization, atomization and others. The adoption and application of these processing techniques in the African quail industry will certainly resolve the problem of short shelf life of the eggs. This will also encourage more people to consume quail egg and egg products.

* **Corresponding Author:** Ekpo Kotchikpa Justin ✉ ekpok.justin@yahoo.fr

Introduction

The Japanese quail (*Coturnix japonica*) is a small, hardy bird belonging to the *Galliformes* order, *Phasianidae* family and of the *Coturnix type*, which is considered the most widespread in the world (Shanaway, 1994). It is reared for meat and egg production. It lays up to 300 eggs per year, making it the typical egg layer available for human consumption (Puigcerver *et al.,* 2012; Rodríguez-Teijeiro *et al.,* 2003). Quail eggs are produced and marketed around the world. Indeed, the largest markets for quail eggs are in France and Japan which are the biggest consumers (Perennou, 2009). Quail rearing provides direct food benefits to the local populace and also presents an alternative strategy for adaptation to climate change, reinforcing global efforts to improve food safety (Jeke *et al.,* 2018b).

Although the production of quail and the consumption of its eggs are widespread, the practice remains new in African countries (Atere *et al.,* 2015; Bakoji *et al.,* 2013; Jeke *et al.,* 2018a). Using Benin (West Africa) as a case study, quail production is practiced in the departments of Oueme (Avrankou and Porto-Novo), Couffo (Dogbo) and Borgou (Parakou) and almost all the quail populations in Benin can be found in these areas (TDH, 2016). However, due to the cost and inaccessibility, the quail eggs are still considered to be reserved for people of high social class with significant financial resources, despite the significant increase in the number of quail in Benin (TDH, 2016). This situation is partly explained by the lack of an organized market for the sale of products that are often sold directly to consumers or rarely through local supermarkets (TDH, 2016). Besides, quail eggs with very small size have a short shelf life which does not favor their transport and marketing over a long period.

These difficulties cause the deterioration of quail eggs resulting in economic losses to quail farmers, consumers and traders of the eggs in Benin. These losses have led some quail farmers to abandon the enterprise. During storage, quail eggs deteriorate physically and are susceptible to bacterial imfestation (Shanaway, 1994). Truffier (1978) reported that quail egg is composed of proteins, vitamins (A, B complex, E), phosphorus, potassium, iron. The author also stated that compared to the hen egg which is about 5 times bigger; quail egg contains 5, 7.5, 6 and 15 times more phosphorus, iron, vitamin B_1, and B_2, respectively. In addition, egg white of many avian species contains ovomucoid, but the egg of quail is an excellent trypsin inhibitor and heat-resistant (Feeney *et al.,* 1969). It is a stable and specific glycoprotein having an inhibitory effect on serine proteases such as trypsin by the formation of a complex enzyme-inhibitor (Vergnaud and Bruttmann, 2007). Recent studies have shown that most inhaled allergens have a "trypsin-like structure" (Widmer, 2000).

In view of the many nutritional and therapeutic values and in this case the mechanism of the ovomucoid, the intake of quail egg prevents, relieves and even cures several diseases such as, ulcers, bronchial asthma, high blood pressure, cough, obesity, sinusitis, diabetes and others (Truffier, 1978).

As egg production increased by about 54% between 2003 and 2012, from 7.200 to 15.858 tons (FAO, 2015), quail eggs should be made accessible and consumed in all households, as in the case of hen eggs which are widely consumed in Benin. The aim of this review was therefore to report on scientific information available on the nutritional, physico-chemical, functional and therapeutic qualities of quail eggs and the processing technologies in order to identify appropriate solutions to the problem of preservation by processing quail eggs into egg products.

Origin and domestication of quail

According to Prabakaran (2003), the term "quail" refers to a group of small birds that crouch or run rather than fly to escape from danger and the term itself means "to sink or tremble with fear". Several authors have reported on the history of quail domestication, but the information available seems to be fragmented. Quails are widely distributed in Europe, Africa and Asia where they are considered as a migratory species with records of existence dating back to ancient civilizations (Ratnamohan, 1985).

The earliest known representation of the quail can be found in Egyptian hieroglyphics 2000 years BC (Shanaway, 1994). Quails have been known for centuries as a source of meat which can be seen in some biblical passages: Numbers (11.27), Exodus (16:7-16.22) and koranic passages: 'El-salwa' (Boni *et al.,* 2010; Sonale *et al.,* 2014; Facolade, 2015). However, European quails would have migrated to the south in autumn across the Mediterranean and would have been easily captured, but the available Egyptian records do not confirm this captivity (Ratnamohan, 1985).

For this reason, it would appear that quails were domesticated in the East and not in the Near East (Shanaway, 1994; Ukashatu *et al.,* 2014). The first writings on the domestication of quails date from the 12th century in Japan (Mills *et al.,* 1997; Shanaway, 1994; Huss *et al.,* 2008; Hrncar *et al.,* 2014). These birds were domesticated in Japan or brought from China (Shanaway, 1994; Huss *et al.,* 2008). During the last 600 years, quails have been kept mainly as songbirds (their rhythmic calls) and in feudal times, their songs were particularly popular to the extent that samurai warriors held competitions to identify the birds with the finest songs for their crossbreeding (Shanaway, 1994). By 1900, quails in Japan had become widely used for meat and egg production (Huss *et al.,* 2008). Between 1910 and 1941, the quail population grew rapidly in Japan and spread to Korea, China and Taiwan (Shanaway, 1994).

At that time, the domesticated population was estimated at about 2 million Japanese quails that were selected for various factors such as plumage colour, body size and egg production (Shanaway, 1994). These selected stocks were greatly lost during the Second World War due to scarcity and feed shortages (Mizutani, 2003; Huss *et al.,* 2008). In 1945, their numbers was drastically reduced (Shanaway, 1994). After the war, the Japanese quail industry was reconstituted from a few remaining domestic and wild-caught birds in addition to domestic lines from Korea, China and Taiwan (Shanaway, 1994). All domestic quail lines currently in the USA and Europe appear to have been derived from this post-war population of Japanese quails (Mills *et al.,* 1997; Huss *et al.,* 2008). It is probably in the 1980s that the domestic quail would have very timidly appeared in sub-Saharan Africa through Christian missionaries who very discreetly imported small flocks (Anonymous, 2010). In Benin, the production of Japanese quails was effective during the revolutionary period in the 1980s, when it was ordered to carry out animal husbandry in all sectors. Thus, the sector of the National Society of Petroleum Consumables (SONACOP) adopted Japanese quails in Benin in 1981. The Non-Governmental Organization (Songhaï) created in 1981 also adopted them four years later. Due to these and other initiatives, quail rearing has spread in some departments (Oueme, Couffo and Borgou) in Benin (TDH, 2016).

Uses of quail eggs

Supposed therapeutic virtues of quail eggs

Since ancient times, quail eggs have already been known for their therapeutic anti-allergic properties. Nowadays, these properties have been proven by clinical studies conducted on several thousands of people suffering from allergic symptoms, both children and adults (Truffier, 1978). This important clinical practice had shown that the patients were completely cured. Some patients had an exacerbation of their symptoms on the third day. This was a normal reaction related to the effectiveness of the treatment. The quantity of quail eggs ingested during the cures resulted, in some patients side effects such as: nausea, gastric pain and hypercholesterolemia. Although these cures gave good results, the presence of these side effects calls for further exploration of the mode of action of these quail eggs and a galenic form (by sublingual and cutaneous way) having the same effectiveness as the whole eggs, in order to reduce these menace. It is therefore important that this information should be known in order to encourage the consumption of quail eggs in Benin.

Quail egg inhibitory properties

Inhibitory properties have been discovered in quail egg. Thus, Lineweaver and Murray (1947) identified the egg white ovomucoid among the different protein fractions. Feeney *et al.* (1969) demonstrated that the ovomucoid of quail egg white was capable of inhibiting the activity of a human enzyme trypsin secreted by the exocrine cells of the pancreas.

It is a protease from the serine protease family whose homologous enzymes can be endogenous (mast cell and neutrophil) or exogenous (allergens, food, drugs, insect bites, etc.). Liu *et al.* (1971) found that quail egg white contained enzyme inhibitors other than the ovomucoid such as ovoinhibitors which are also natural serine protease inhibitors and have potent activity on bovine trypsin, subtilisin secreted by *Bacillus subtilis* and the fungal proteinase from *Aspergillus orizae*. A Canadian study has also shown that the ovomucoid of the quail egg has potent activity against elastase (serine protease), which is involved in many pathologies in humans, particularly in the pulmonary emphysema and psoriasis. Takahashi *et al.* (1994) found that among all avian species, the Japanese quail egg white ovomucoid was the only one capable of inhibiting human trypsin. Ludolph-Hauser *et al.* (1999) applied elastase (neutrophil serine protease) to healthy skin, in increasing concentrations to cause psoriatic skin lesions.

Elastase induces typical epidermal lesions followed by an acute sub-epidermal and dermal inflammatory reaction with an influx of neutrophil polynuclear cells which release large amounts of elastase in situ. Vergnaud and Bruttmann (2007) studied and confirmed the inhibitory effect of the Japanese quail egg's ovomucoid on human trypsin and elastase activity. Their results showed that the purified ovomucoid had a strong inhibitory effect on the activity of both bovine and human trypsin and a weak but significant inhibition on the activity of elastase of porcine or human origin. These results suggest a strong specificity of the ovomucoid in its properties of inhibiting the catalyzed activity of trypsin.

The competitive nature of this inhibition justifies the repeated administration of a cure with a high dose of Japanese quail eggs to patients as food supplement and the observed improvement. According to these same authors, a galenic form suitable for the use of purified ovomucoid in the treatment of patients suffering from allergic diseases could contribute to breaking the observed inflammatory process. Thus, Bruttmann (2007) investigated the stability of Japanese quail egg ovomucoid called: "Standardized Extract of Quail Eggs (ESOC) or homogenate". The process for obtaining this homogenate in powder form is patented. Ultimately, the homogenate makes it possible to manufacture different galenic forms such as:

- Beminovum: a food supplement in the form of tablet based on quail egg with added zinc.
- Sublingual tablet, which is a food supplement with a low dosage of active component, the efficacy of which is the same as that obtained by Truffier with 6 whole eggs recommended in a single dose.
- Cream, containing a suitable excipient which acts in synergy with the active product on skin disorders.

The constant evolution of biotechnology has enable Bruttmann *et al.* (2013) to explain the mechanism of action of ESOC completely innovative and covered by numerous patents. According to Bruttmann *et al.,* (2013) allergens (pollen, mites, animal hair, etc...) do not represent any danger to humans. However, in some people, contact with an allergen triggers an elaborate defense mechanism known as allergic disease. At the tissue level, the allergen is captured, analyzed and then information on the body's defenses is set up and transmitted to the T-lymphocytes and then to the B-lymphocytes. The latter produce specific antibodies called type E immunoglobulin (IgE) which combats the allergen, considered as a dangerous invader. The ovomucoid significantly reduces the production of IgE antibodies and effectively inhibits the release of histamine from basophils. The ovoinhibitor is one of the serine protease inhibitors and strongly inhibits elastase and bacterial and fungal proteases (Bruttmann *et al.,* 2013).

By studying the inhibitory activity of ovomucoid in 10 avian species, Takahashi *et al.* (1994) reported that Japanese quail egg ovomucoid was the most potent ovomucoid of all avian species and the only one to inhibit human trypsin. Lianto *et al.* (2018) demonstrated that a whole quail egg was able to relieve allergic symptoms induced by food allergies.

These results confirmed that quail egg white and yolk together perform anti-allergic activity and can be used as a potentially anti-allergic food in the future. Taking this information into account, it is evident that quail eggs prevent, relieve and cure diseases especially allergies.

Quail egg composition, qualities and properties

Physico-chemical composition and nutritional qualities

Small size Japanese quail eggs are four times richer in nutrients than chicken eggs (Genchev, 2012). They contain more crude protein, crude fat and mineral ash than the eggs of hen, guinea fowl and pheasant (Chepkemoi *et al.,* 2015; Song *et al.*, 2000). Jeke *et al.* (2018a) confirmed these results by pointing out that Japanese quail eggs contain a relatively high content of crude protein (13.09 grams / 100 grams) that is limited in the human diet. Some scientific studies on the characterization of the protein quality of quail eggs have shown the presence of sufficient amounts of essential amino acids such as lysine (790 milligrams / 100 grams), valine (869.5mg / 100g) and leucine (Flodin, 1997; Layman and Walker, 2006). The non-essential amino acids are aspartic acid (1488mg / 100g) and alanine (739.0mg / 100g) (Genchev, 2012). Japanese quail eggs also contain enough polyunsaturated fatty acids, including omega 3, which are important in preventing cardiovascular diseases (Dvorska *et al.,* 2001; Mennicken *et al.,* 2005; Sinanoglou *et al.,* 2011).

Thus, the consumption of Japanese quail eggs helps prevent diseases due to nutrient deficiency and contributes significantly to the health of communities (da Silva *et al.,* 2009). Comparing Japanese quail eggs with those of other poultry species such as chicken (*Gallus gallus*), turkey (*Meleagris gallopavo*), guinea fowl (*Numida meleagris domestica*) and pigeon (*Columbia livia domestica*), Japanese quail eggs have been shown to contain the highest levels of essential trace elements such as manganese (Mn), iron (Fe), cobalt (Co) and copper (Cu) (Abduljaleel *et al.,* 2011). Japanese quail eggs have also been shown to contain insignificant amounts of non-essential metallic arsenic which is harmful to human health (Abduljaleel *et al.,* 2011; Jorhem, 2014). This very low arsenic (As) content makes the consumption of quail eggs relatively safer and healthier than those of other poultry species, including chicken eggs that are widely consumed.

Quail eggs have a greater nutritional composition advantage over other types of poultry and can play a crucial role in addressing global dietary problems, especially one regarding protein shortage in developing countries (Genchev, 2012; Genchev *et al.,* 2006; Tunsaringkarn *et al.,* 2013). Japanese quail eggs are an important source of nutrients for the fight against malnutrition and significantly contribute to improving the livelihoods of local populations, thus promoting sustainable development (Biswas *et al.,* 2015). Therefore, to avoid rotting and ensure continuous availability of quail eggs, they should be processed into egg products which are more conservable over time. In addition, the production of Japanese quail needs to be revitalized especially in developing countries to improve food safety (Bakoji *et al.,* 2013; Wahab, 2002). However, the question remains, will the increasing demand for animal proteins and the growing population in developing countries encourage the consumption of Japanese quail egg products?

Functional qualities

Eggs are multifunctional and widely used as an ingredient in many food applications (Yang and Baldwin, 1995). The functional attributes provided by eggs include the following properties: coagulation and binding, flavor, colour, foam, emulsion and prevention of crystallization in confectionery products (Froning *et al.,* 2002). Coagulation and binding are important in foods such as cooked meat products and pastry creams. The main proteins contributing to the attributes of coagulation are conalbumin, globulins, ovalbumin and lysozyme (Froning *et al.,* 2002).

The superior foaming properties of eggs are difficult to replicate with other ingredients. Eggs produce foams of excellent volume like angel food: cakes, sponge cakes, meringues, soufflés and omelets (Froning *et al.,* 2002). According to the same authors, several egg proteins contribute to the foaming properties. Globulins increase viscosity and decrease the surface tension. Ovalbumin and conalbumin have thermosetting properties. Ovomucin forms an insoluble film that stabilizes the foam. Eggs impart emulsifying properties to mayonnaise, salads, vinaigrettes and cream puffs (Froning *et al.,* 2002). A combination of components including lipoproteins, phospholipids and cholesterol contribute to the optimal emulsifying power of eggs. Egg yolk proteins, such as lipovitellin, vivetin and lipovitellenin, function as surfactants, to stabilize the film around the oil globule to form an emulsion (Froning *et al.,* 2002). Cotterill *et al.* (1963) have observed that egg white inhibited the growth of sugar crystals in candies. They also found that egg white inhibited syneresis, excessive evaporation and fluidity due to sucrose inversion.

Egg white proteins are particularly sensitive to heat damage; therefore pasteurization can affect the functional properties of the egg. Pasteurization temperatures between 54°C and 60°C have been shown to damage the foaming properties of egg white (Cunningham, 1995). Heating above 57°C damages the egg white and increases the whipping time (Froning *et al.,* 2002). Whipping agents, such as triethyl citrate and sodium lauryl sulphate, can help restore the foaming property of heat-damaged egg white (Cunningham, 1995).

Studies indicated that pasteurizing the whole egg at 61°C for 3 min did not affect the yield of pastry creams, but had a slight impact on yield by altering the quality of sponge cakes (Cunningham, 1995). However, pasteurization temperatures for whole eggs above 60°C can have a negative effect on the sponge cake volume. Herald and Smith (1989) observed that pasteurizing the whole egg between 60°C and 68°C reduced the expansion of the pie filling. Pasteurization of egg yolk products appears to have minimal effects on emulsifying properties (Cunningham, 1995).

The pasteurization of salted egg yolk between 62°C and 64°C had no negative effect on the performance of mayonnaise and cream puffs (Froning *et al.,* 2002). Other studies have indicated that sweetened egg yolks pasteurized at 60°C to 64°C perform well in sponge cakes, chiffon cakes and yellow layer cakes.

Anti-microbiological properties

With the exception of *Salmonella enteritidis*, most of the egg bacterial contamination occurs after laying, when eggs are exposed to the environment, feces and moisture. Thus, several bacterial and fungal species can become potential contaminants of eggs, including *Salmonella* (Board and Tranter, 1995). The shell egg has both physical and chemical barriers against microorganisms. The cuticle of the eggshell prevents some invasion of bacteria, but it is usually exposed during egg washing off because the egg shell contains between 9.000 and 10.000 pores about 10-30 micrometer in diameter, allowing easy bacterial penetration (Board and Tranter, 1995). Messens *et al.* (2005) indicated that the increased thickness of the shell reduces the penetration rate of *Salmonella*. The eggshell consists of two distinct membranes that are the most important physical barriers to the penetration of microorganisms into the egg. Haines and Moran (1940) reported that these shell membranes act as bacterial filters. However, several researchers have observed that the inner membrane of the eggshell is more effective in preventing bacteria than the outer membrane (Reu, 2008; Jan, 2019; Befungi *et al.,* 1999; Liftshitz *et al.,* 1965). It is possible that albumen proteins such as lysozyme contribute to the resistance of shell membranes to microbes (Wu, 2014). It was reported that disruption of the enzymatic mechanism of the membranes may promote bacterial penetration, but Wedral *et al.* (1971) indicated that enzymes do not change the permeability of the membranes to *Salmonella*.

Albumen has both mechanical and chemical defenses against microbial growth (Board and Tranter, 1995). The viscosity of albumen, which is derived from the fibers of ovomucin, prevents the movement of bacteria from the albumen to the egg yolk (Wu, 2014). In addition, the thick albumen bag centers the egg yolk, creating a greater distance for the bacteria to move after migration through the shell membrane (Wu, 2014). With regard to chemical defenses, albumen has several proteins with antimicrobial properties (Table 1).

Lysozyme lyses the cell wall of Gram-positive bacteria. Wang and Shelef (1991) observed that lysozyme was an effective inhibitor of *Listeria monocytogenes*. In addition, they indicated that the anti-listeria activity of lysozyme was enhanced by ovomucoids, conalbumin and alkaline pH. Gast and Holt (2000) inoculated *Salmonella enteritidis* in egg white and noted poor growth at different temperature (10°C, 17.5°C or 25°C) for 3 days. Although lysozyme is largely ineffective against Gram-negative bacteria, such as *Salmonella*, in combination with other proteins, such as ovotransferrin (conalbumin), which chelate metal cations, can delay the growth of these bacteria (Gast and Holt, 2000). In addition, an alkaline pH (9.3 to 9.5) improves the chelating potential of ovotransferrin (Board and Tranter, 1995).

Several other egg white proteins can inhibit bacterial growth by enzymatic or vitamin inhibition (Table 1). The effect of these proteins depends on the nutrient requirements of the bacterium in question. Although shell membranes and albumen provide barriers to microbial growth, egg yolk is a good nutritious environment for the growth of *Salmonella enteritidis* (Lakins *et al.,* 2008; Okamuram *et al.,* 2008). Gast and Holt (2000) observed that *Salmonella enteritidis* grew fast in egg yolk at temperatures of 17.5°C and 25°C, but that growth was much slower at 10°C.

This further supports the new USDA requirement that eggs must be stored and transported at an ambient temperature below 7°C (USDA. 1998).

Table 1. Antimicrobial proteins in egg albumen (Froning *et al.,* 2002).

Proteins	Action mode	Role
Lysozyme	Hydrolysis of β (1-4) glycoside contained in the bacterial cell wall	Effective against gram-positive bacteria except *Salmonella*
Ovotransferrin	Chelate metal cations (Fe. Cu. Mn Zn) making them unavailable to microorganisms.	Particularly effective against spoilage bacteria
Avidin	Binds biotin, making it unavailable to bacteria.	Depends on bacterial requirements for this vitamin
Ovomucoid	Inhibits trypsin	Unknown role
Ovoinhibitor	Inhibits trypsin, chymotrypsin, subtilisin, elastin	Unknown role
Ovomacroglobulin	Inhibits trypsin, papain	Unknown role
Cystatin	Inhibits papain, bromelain, ficin	Unknown role
Flavoproteins	Binds to the riboflavin, making it inaccessible to bacteria	Depends on bacterial requirements

Egg processing technology

Pasteurized egg technology

Pasteurization requirements of various liquid egg products are shown in Table 2. These USDA requirements provide minimum temperatures and holding times (FDA, 2002; USDA, 1980). Pasteurization requirements for whole eggs for other countries are from 66°C to 68°C for 1 minute for Poland; 63.3°C for 2.5 minutes for China; 62°C for 2.5 minutes for Australia; 65°C for 90 to 180 seconds in Denmark and Great Britain requires a temperature of 64.4°C for 2.5 minutes (Cunningham, 1995). Michalski *et al.* (1999) using a plate pasteurizer reported a reduction of *Salmonella enteritidis* greater than 9 D in whole egg at 60°C for 3.5 minutes. Ball *et al.* (1987) developed a process for processing whole egg into ultra-pasteurized and aseptic in order to extend its shelf life. The whole egg was heated at temperatures between 63.7°C and 72.2°C for 2.7 to 192.2 seconds.

Other methods of pasteurization

Pasteurization by irradiation has been the subject of numerous studies. Many previous research efforts have been revised in the "Manual of Egg Pasteurization" (USDA, 1968). Gamma irradiation was then preferred. Gamma radiation has excellent penetration, especially with frozen egg products (Froning *et al.,* 2002). Egg products containing egg yolk have been noted to have unpleasant aromas that volatilized during spray drying. Egg white was less subject to the development of unpleasant aromas during gamma irradiation. Kijowski *et al.* (1994) observed that gamma irradiation of whole frozen eggs at 2.5 kgy did not modify the functional or sensory properties. They obtained a D-value of 0.39 kgy.

Table 2. USDA Pasteurization Requirements (USDA, 1980).

Liquid egg products	Minimum temperature (°C)	Minimum holding time (minute)
Albumen (without the use of chemicals)	56.7	3.5
	55.6	6.2
Whole egg	60.0	3.5
Whole eggs	61.1	3.5
(less than 2% non-egg ingredients added)	60.0	6.2
Whole eggs enriched with (24-38%)	62.2	3.5
Solids and 2-12% non-egg ingredients added)	61.1	6.2
Salted whole egg (with 2% or more salt added)	63.3	3.5
	62.2	6.2
Sweetened whole egg (with 2% or more added sugar)	61.1	3.5
	60.0	6.2
Natural egg yolk	61.1	3.5
	60.0	6.2
Sweetened egg yolk (2% or more added sugar)	63.3	3.5
	62.2	6.2
Salted egg yolk (2-12% salt added)	63.3	3.5
	62.2	6.2

There are other equivalent methods that have also been used and approved. Further research on the use of electron beam irradiation stimulated new interest in this technology (Wong *et al.,* 1996; Huang *et al.,* 1997; Serrano *et al.,* 1997). Electron beam irradiation did not generate radioactivity when the accelerator was turned off. In addition, there was no radioactive waste, which poses a problem when Co-60 is used as a gamma source. However, the electron beam radiation has a low penetration and is limited to use in food of limited thickness (3 cm for a beam power of 8.1 Kilowatts). Serrano *et al.* (1997) inoculated shell eggs and liquid whole eggs with five strains of *Salmonella enteritidis* and irradiated them with an electron beam accelerator.

They noted that a dose of 0.5 kgy was enough to remove all isolates from the shell surface. Based on the D-values obtained, an irradiation dose of 1.5 kgy was sufficient to reduce *Salmonella* numbers by 4 logs in shell eggs and liquid eggs. Wong *et al.* (1996) discovered that electron beam irradiation of liquid egg white at a concentration of 2.5 to 3.3 kgy destroyed an inoculum of 107 cells per milliliter of nalidixic acid resistant to the *Salmonella typhimurium* strain. Min *et al.* (1997) used electron beam irradiation at 2.5 kgy on pasteurized liquid egg yolk and this irradiation had no significant negative effect on the physical, chemical and functional properties of the egg yolk.

The FDA (2000) approved the use of ionizing irradiation for the reduction of *Salmonella* in fresh shell eggs. It was reported that the absorbed dose of 3 kgy resulted in some changes in viscosity and colour. However, no effect on the chemical composition was indicated. It was pointed out that this dosage reduced, but did not eliminate *Salmonella*. Irradiation can have a potential on the pasteurization of liquid eggs. Electron beam irradiation can probably be worth continuing to eliminate *Salmonella* from the egg white, which is very sensitive to heat. However, consumer acceptance of irradiation is currently a concern (Froning *et al.,* 2002).

The Institute of Food Technologists (2000) examined several alternative methods of pasteurizing food products. These include microwave and radiofrequency treatment, ohmic heating, high pressure treatment, pulsed electric field, high voltage arc discharge, pulsed light technology, oscillating magnetic fields, ultrasound and pulsed radio. Some of these may have future commercial benefits, but they are currently largely experimental (Froning *et al.*, 2002). Currently, only chicken eggs are pasteurized; it would be interesting and necessary to also pasteurize quail eggs in order to improve quail industry in Benin.

Processing of eggs into powder

Trials for producing of quail egg powder have already been carried out in the past.

Thus, Truffier and Pinon. (1983) obtained a patent describing a process for preparing an ovomucoid fraction with protease activity from quail egg white. The inventors found that for the treatment of immuno-allergic diseases, the raw egg can be replaced by a freeze-dried quail egg of strain B Mina or other strains.

The process for preparing freeze-dried quail egg consisted of separately removing the content of each egg by aspiration with a sterile syringe connected to a vacuum pump. Egg content was then pasteurized at 64°C for 5 min and underwent freeze-drying by lowering the temperature to -40°C under sub-atmospheric pressure and then heating at 40°C to eliminate the water. Finally, the freeze-dried quail egg underwent regulatory bacteriological and mycological controls for the egg products before being used. It was packaged in sachets containing 6 grams of the powder corresponding to 3 freeze-dried quail eggs. Zhao *et al.* (2006) worked on the freeze-drying of the egg and measured by the resistance method the eutectic temperatures of the egg white, egg yolk and whole egg. The freeze-drying kinetic curves of the three powders were analyzed by repetitive experiments. Song *et al* (2007). used whole quail egg liquid to study the quail egg powder technology and recorded that the freezing temperature was -30°C for 17 hours drying time and 5 mm thickness. Zhang and Chen (2005) were concerned with the technology of processing liquid quail egg yolk into powder and the results of their work showed that hot air drying and microwave drying were not suitable for the processing of quail egg yolk into powder. They also determined the optimal conditions for spray drying of liquid quail egg yolk. It was inferred that the type and characteristics of the equipment used, were decisive for the quality of the final products. Ultimately, all of the results of the studies on the technologies of egg powder production showed that to address the problem of the preservation of quail eggs in Benin, quail eggs can be freeze-dried and atomized for consumption as a complete food in Benin.

Conclusion

Finally, several scientific studies have shown the important values of quail eggs through their richness in nutrients that are very essential for human. Nutrients such as proteins, vitamins, minerals, essential amino acids, omega 3 fatty acids and others make Japanese quail eggs an excellent nutritious food. They are the best of all eggs compared to other poultry species.

More interestingly, quail eggs are endowed with extraordinary therapeutic values that are partly related to the mechanism of their power to inhibit serine proteases. Thus, the consumption of quail eggs prevents, relieves and cures several diseases. Some studies have looked into the processing of quail eggs into powder using various technologies.

These powders have been used in manufacturing of drugs, cosmetics and other products. However, quail eggs should be processed into egg products and consumed as a complete food and not as a nutraceutical. Through that, the crucial problem of quail egg preservation would also be solved in Benin and elsewhere.

Value addition would further promote the commercialization of quail eggs production in Benin.

Acknowledgement

Our sincere appreciations go to the management of the Regional Center of Excellence in Poultry Sciences (CERSA), University of Lome, Togo and the World Bank for funding the research work.

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