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Experimental Approach to Preserving Eggs Using the Century Egg Method

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In expressing my gratitude, I strive to maintain a humble perspective, recognizing that any achievements or merits are not solely my own. I am but a humble servant, and any positive outcomes are a reflection of the Almighty's blessings and the grace bestowed upon me. It is with a deep sense of humility that I offer my thanks, understanding that true success and fulfillment come from aligning our efforts with the will and wisdom of Allah.

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Declaration on Honor

I, the undersigned, **BOUKHATEM AMEL SABRINE**, declare that I’m fully aware that plagiarism of documents or part of a document published in any form, including on the internet, constitutes a violation of copyrights and an act of fraud. Consequently, I commit to citing all sources that I used to write this thesis.

Signature

Dedication

To my beloved mother, KHATTOU Riala, who is no longer with us. Your unwavering love, guidance, and support continue to inspire me every day. This work is dedicated to your memory, with all my love and gratitude. You are always in my heart.

To my beloved father, thank you for your unwavering encouragement and for compelling me to pursue higher education.

I am forever grateful to my dear aunt for her kindness, generosity, and unconditional love, without which I would not be where I am today.

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Finally, I dedicate this work to the Palestinian people, especially those in Gaza, who are enduring the hardships of war and starvation. Your faith and endurance have been a profound inspiration, and I am committed to making food security a top priority, in the hope that I may one day be able to contribute to alleviating your suffering.

Résumé

L'objectif de cette recherche est d'explorer le potentiel d'introduction du pidan, une méthode ancienne de conservation des œufs couramment utilisée dans les pays asiatiques, en tant que nouveau produit à base d'œufs sur le marché algérien, qui connaît une demande croissante pour les œufs avec une variété de produits limitée. Le pidan, également connu sous le nom d'œufs centenaires ou œufs conservés, est une délicatesse qui subit un processus de fermentation unique, résultant en une saveur et une texture distinctives. Étant donné le manque d'exposition à ce produit en Algérie, nous visons à étudier la faisabilité d'incorporer le pidan dans le paysage alimentaire local.

Pour ce faire, nous avons utilisé la méthode expérimentale pour évaluer le processus de fabrication des œufs centenaires en utilisant la technique d'immersion. Cela a impliqué la mise en saumure des œufs avec une solution contenant de l'hydroxyde de sodium, du sel et l'évaluation des changements dans leurs caractéristiques organoleptiques, telles que la couleur, l'arôme et la texture, à la fin du processus. Le processus de mise en saumure dure généralement de plusieurs semaines à plusieurs mois, en fonction du niveau de fermentation souhaité.

Nos résultats ont démontré qu'il est possible de produire des œufs de pidan authentiques avec la bonne concentration et la durée de mise en saumure, conformément aux études précédentes sur ce sujet. Les œufs ont subi une transformation, développant un jaune d'œuf de couleur vert sombre et gélatineux et un blanc translucide, semblable à de la gelée. Le profil de saveur a évolué de l'arôme initial d'ammoniac à une saveur riche, savoureuse et légèrement sulfurée.

Cependant, nous concluons que, bien que le processus soit simple, il nécessite une attention minutieuse à chaque étape et est assez chronophage. De plus, la forte saveur et l'apparence frappante de l'œuf peuvent poser des défis lors de son introduction sur un marché non familier avec ce produit. Les consommateurs habitués aux œufs frais peuvent être réticents à essayer le pidan en raison de ses caractéristiques uniques, nécessitant une stratégie de marketing bien planifiée pour éduquer les consommateurs et promouvoir son acceptation.

Mots clés : Pidan, Fermentation, Marinage alcalin, Caractéristiques organoleptiques, Technique d'immersion, Faisabilité.

ملخص

الهدف من هذا البحث هو استكشاف إمكانية إدخال بيض المئة سنة، وهي طريقة قديمة لحفظ البيض تستخدم عادة في البلدان الآسيوية، كمنتج بيض جديد في السوق الجزائرية التي تشهد طلبًا متزايدًا على البيض مع تنوع محدود في المنتجات.بيض القرن، المعروف أيضًا باسم البيض المئوي أو البيض المحفوظ، هو طعام شهي يخضع لعملية تخمير فريدة، مما ينتج عنه نكهة وقوام مميزان. نظرًا لقلة التعرض لهذا المنتج في الجزائر، نسعى إلى دراسة جدوى دمج هذا البيض في المشهد الغذائي المحلي.

لتحقيق ذلك، استخدمنا الطريقة التجريبية لتقييم عملية صنع البيض المئوي باستخدام تقنية الغمر. تضمن ذلك تخليل البيض بمحلول يحتوي على هيدروكسيد الصوديوم والملح، وتقييم التغييرات في خصائصه الحسية مثل اللون والرائحة والقوام في نهاية العملية. تستغرق عملية التخليل عادةً من عدة أسابيع إلى عدة أشهر حسب مستوى التخمير المطلوب.

أظهرت نتائجنا أنه من الممكن إنتاج بيض القرن أصلي باستخدام التركيز الصحيح ومدة التخليل المناسبة، بما يتوافق مع الدراسات السابقة حول هذا الموضوع. خضع البيض لتحول، حيث تطور صفار البيض إلى لون داكن وهلامي وبياض شفاف يشبه الجيلي. تطورت النكهة من الرائحة الأولية للأمونيا إلى طعم غني بنكهة قليلة من الكبريت.

ومع ذلك، نستنتج أنه رغم أن العملية بسيطة، إلا أنها تتطلب اهتمامًا دقيقًا في كل خطوة وهي مستهلكة للوقت. بالإضافة إلى ذلك، قد تشكل النكهة القوية والمظهر اللافت للبيض تحديات عند تقديمه إلى سوق غير مألوف بهذا المنتج. قد يكون المستهلكون الذين اعتادوا على البيض الطازج مترددين في تجربته بسبب خصائصه الفريدة، مما يستلزم استراتيجية تسويق مخططة جيدًا لتثقيف المستهلكين وتعزيز قبوله.

الكلمات الرئيسية: بيض المئة عام(Pidan) ، التخمر، ، الخصائص الحسية (العضوية)، تقنية الغمر، خليل القاعدي .

Abstract

The purpose of this research is to explore the potential of introducing pidan, an ancient method of preserving eggs commonly used in Asian countries, as a novel egg product in the Algerian market, which is experiencing an increasing demand for eggs with limited product variety. Pidan, also known as century eggs or preserved eggs, is a delicacy that undergoes a unique fermentation process, resulting in a distinctive flavor and texture. Given the lack of exposure to this product in Algeria, we aim to investigate the feasibility of incorporating pidan into the local food landscape.

To achieve this, we employed the experimental method to evaluate the process of making century eggs using the immersion technique. This involved pickling eggs with a solution containing sodium hydroxide, salt, and assessing the changes in their organoleptic characteristics, such as color, aroma, and texture, at the end of the process. The pickling process typically takes several weeks to several months, depending on the desired level of fermentation.

Our results demonstrated that it is possible to produce authentic pidan eggs with the correct concentration and duration of pickling, consistent with previous studies on this topic. The eggs underwent a transformation, developing a dark-colored, gelatinous yolk and a translucent, jelly-like white. The flavor profile evolved from the initial ammonia-like aroma to a rich, savory, and slightly sulfurous taste.

However, we conclude that while the process is straightforward, it requires careful attention at each step and is quite time-consuming. Additionally, the egg's strong flavor and striking appearance may pose challenges when introducing it to a market unfamiliar with this product. Consumers accustomed to fresh eggs may be hesitant to try pidan due to its unique characteristics. necessitating a well-planned marketing strategy to educate consumers and promote its acceptance.

Key word: Pidan, Fermentation, Alkaline pickling, Organoleptic characteristics, Immersion technique, feasibility.

Sommaire

List of Figures

List of Tables

Bibliographic section

Introduction:

For centuries, eggs have been a crucial component of the human diet, serving as an excellent source of essential nutrients like proteins, vitamins, minerals, and fatty acids. The egg, with its two main compartments—the yolk and the egg white—offers valuable functional characteristics. These include the ability to foam and gel, making eggs a preferred ingredient in the preparation of numerous dishes and meals. This prominence has led to extensive research and technological advancements focused on ensuring a consistent and ample supply of eggs to meet the growing demand and produce a variety of products.

Algeria, being one of the largest countries with a growing population, has experienced increased egg production and consumption, reaching 28 million eggs per day, as reported by a representative of egg traders. Despite this, the market lacks diversity in egg products compared to global leaders like China, the largest egg-producing country, annually producing approximately 462 billion eggs. With a substantial poultry population, China offers various types of eggs, one of which has gained recent popularity—the century egg. This unique egg has become a social media challenge, prompting questions about its origins, production process, and the changes that occur inside the egg through this method. What exactly is a century egg, how was it discovered, and what transformations take place during its creation?

Our objective is to conserve eggs using this preservation method and assess the changes that occur by the end of the experiment.

I.Egg definition, structure, and general composition

I.1.Definition:

The egg, generally referring to a chicken egg, is an oocyte surrounded by nutritional reserves and a protective barrier, enabling embryo growth without maternal contact. It can be either fertilized or unfertilized. Throughout its journey in the hen's genital tracts, all necessary resources for its development are deposited inside the egg. These resources include nutrients, protective systems, as well as regulatory and effectors molecules. These constituents boast good digestibility within the enclosed environment where waste elimination is not possible. The egg comprises seven basic parts: the shell, membranes, albumen, yolk, chalazae, germinal disc, and air sac. Each part has a specific role to fulfill and serves a distinct purpose. (**Handbook of Egg Science and Technology- 1st Edition Yoshinori Mine 2023)**

I.2.Structure and general composition of the egg

I.2.1. The eggshell:

The eggshell serves as the outer protective layer encompassing all components of the egg. In most bird species, it constitutes approximately 10-11% of the egg's weight. Composed mainly of calcite crystalline, calcium carbonate and organic matter, its primary function is to shield the embryo from external threats. It must prevent bacterial infiltration, withstand external pressure, and facilitate hatching. Additionally, it allows gas exchange during embryo development due to the presence of tiny pores, imparting the egg with its characteristic grainy texture **(Nys et al., 1999)**. The shell can be divided into five distinct layers from the inner region to the periphery:

a. Shell Membranes: There are two membranes—an inner and outer one—both situated just inside the shell, enclosing the albumen. These robust, transparent protein membranes, partially made of keratin, safeguard against bacterial invasion. The outer membrane adheres to the eggshell, while the inner membrane attaches to the albumen.

b. Mammillary Layer: This layer corresponds to the most internal part of the calcified layer. It serves as the base for mineralization initiation, extending outwardly to form cone-like structures.

c. Palisade Layer: Beginning with the growth of mammillary cones, this layer progresses to the fusion of adjacent cones. It consists of a compact mineral layer associated with an organic framework, except for pores traversing the shell from one side to the other, formed in the absence of cone fusion.

d. Superficial Layer of Vertical Crystals: This thin layer comprises vertically deposited crystals atop the palisade layer, beneath the cuticle.

e. Cuticle: The outermost layer of the egg, composed of organic matter, predominantly contains the pigment responsible for the brown coloration. It covers the pores, inhibiting bacterial penetration, and allows gas exchange through cracks that emerge as the cuticle dries **(Nys et al.,2004)**

I.2.2. The albumen:

The albumen, commonly known as the ‘white,’ is a gel-like structure primarily composed of water (approximately 87%). It comprises three main parts—inner, middle, and outer layers—each varying in thickness, surrounding and protecting the yolk. This viscosity is believed to depend on ovomucin. Additionally, the egg white contains chalazae, structures anchored to the yolk to stabilize it. Made of twisted fibers resulting from the egg's continuous rotation during formation in the oviduct, these fibers are composed of ovomucin and lysozymes. Albumen is rich in proteins such as ovalbumin, accounting for over 50% of total egg white proteins **(Mann,2007)** providing essential amino acids for embryo growth. It also contains a high concentration of lysozyme, possessing antimicrobial properties. Furthermore, it contains four highly abundant protease inhibitors—ovoinhibitor, cystatin, ovomucoid, and ovostatin—that prevent uncontrolled proteolytic degradation of proteins, contributing to its hygienic quality and stability during storage. These proteins, present in fertile eggs, aid in development or, if infertile, are consumed by humans (**Guyot et al.,2017)**

I.2.3. The vitelline membranes:

The vitelline membrane, an extracellular protein matrix encasing the egg yolk and separating it from the egg white, consists of two layers: the inner and outer vitelline membrane. It consist of approximately 88% water and is primarily composed of proteins, it also contains small amounts of carbohydrates, lipids, and minerals**. (Chung et al.,2010)**

I.2.3.1. The inner vitelline membrane

Forms an entangled network of fibers akin to the mammalian zona pellucida, crucial for oocyte-sperm recognition and fertilization. Research has identified several glycoproteins within this layer, notably ZP1, ZP3, and ZPD, which are the most abundant components of this membrane **(Okumura et al., 2004).**

2.3.2. The outer vitelline membrane

Is a thick layer with multiple sublayers of fine fibrils arranged in a crossed pattern. This membrane predominantly contains lysozymes, ovomucin, VMO1, and VMO2, although their exact proportions remain uncertain. **(Kido et al.,1992)**

I.2.4. The yolk:

The yolk, situated at the center of an egg, typically displays a yellow hue, though its color can vary based on the chicken breed, ranging from a light yellow to a deep orange. Comprising approximately 55% water, and 15% proteins, predominantly low-density lipoproteins (LDLs) over high-density lipoproteins (HDLs), along with other soluble and insoluble proteins such as levitins and phosvitins . The major proteins found in the yolk include vitellogenin-1, -2, and -3, apovitellenin, and avidin-related proteins, all unique to eggs and vital for their formation and function as a self-contained reproductive chambers. Additionally, 27% of its composition consists of lipids, primarily forming part of the lipoprotein structure correspond to saturated fatty acids, monounsaturated fatty acids and polyunsaturated fatty acids. It is also rich in vitamins such as D, E, B2, and B5 (excluding vitamin C). The yolk also contains essential minerals like phosphorus, calcium, and serves as a significant source of chlorine. **(Réhault-Godbert et al.,2019)**

The germinal disc: is a small white spot on the yolk it is where the sperm enters the egg and where the embryo would start to grow by a process of cell division . If the germinal disc is fertilized it will then be called a blastoderm.

I.2.5. The air sac:

The air sac, also referred to as the ‘air space’ or ‘air cell’, develops when the contents of a freshly laid egg cool, causing them to contract. Positioned between the outer and inner membranes at the egg's larger end, this air sac expands as the egg matures, irrespective of fertility. Moisture and carbon dioxide exit the egg, while air enters to replace them, leading to the gradual enlargement of the air sac. It also serves as a tiny shock absorber during early embryonic development.

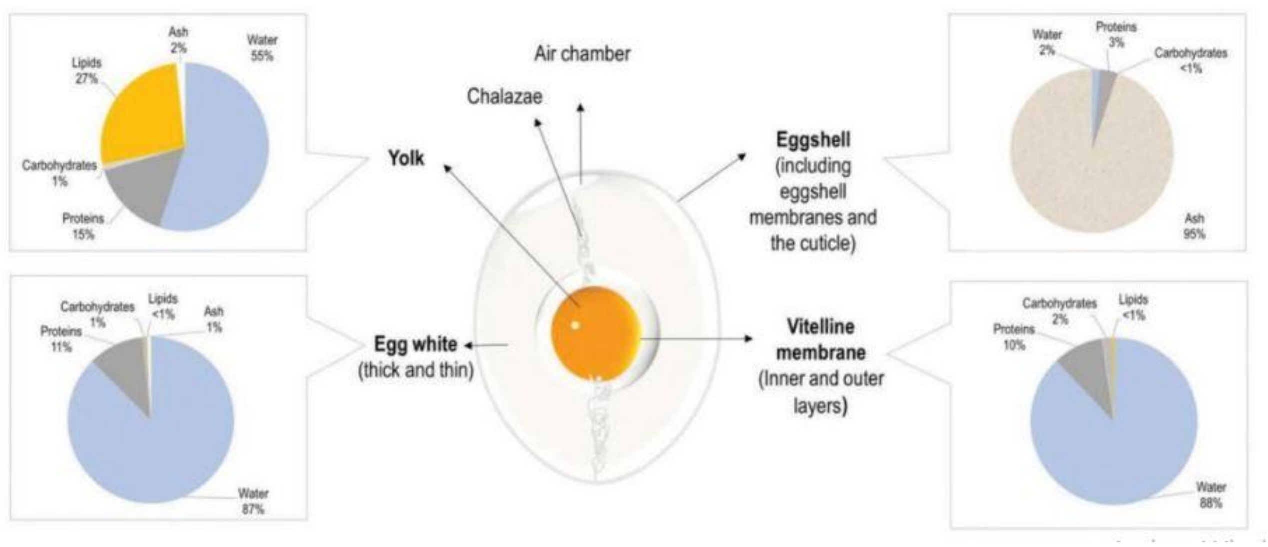

Figure 1 an overview of the egg macroscopic structure and composition (Handbook of Egg Science and Technology- 1st Edition Yoshinori Mine 2023)

Tableau 1 nutritional composition of hen eggs , quantities represent an edible portion of 100g (Miranda, Jose & Antón Vázquez, Xaquín et al., (2015). Egg and Egg-Derived Foods: Effects on Human Health and Use as Functional Foods)

Component(unit)	Amount	Component(unit)	Amount
Egg shell (%)	10.5	Calcium (mg)	56.0
Egg yolk (%)	31	Magnesium (mg)	12.0
Egg white (%)	58.5	Iron (mg)	2.1
Water (g)	74.5	Phosphorus (µg)	180.0
Energy (Kcal)	162	Zinc (mg)	1.44
Protein (g)	12.1	Thiamine (mg)	0.09
Carbohydrates (g)	0.68	Riboflavin (mg)	0.3
Lipids (g)	12.1	Niacin (mg)	0.1
Saturated fatty acids (g)	3.3	Folic acid (µg)	65.0
Monounsaturated fatty acids (g)	4.9	Cyanocobalamin (µg)	66.0
Polyunsaturated fatty acids (g)	1.8	Pyridoxine (mg)	0.18
Cholesterol (mg)	410	Retinol equivalents (µg)	227.0
Iodine (µg)	47	Potassium (mg)	147
Tocopherols (µg)	1.93	Carotenoids (µg)	10
Selenium (µg)	10	Cholecalciferol (µg)	1.8

II. Preserved egg definition and history

In Western countries, the focus of preserving eggs is mainly on restraining bacterial proliferation. Whereas in Asian countries such as China, methods have been developed to induce chemical and physical changes in the yolk and egg white, thereby introducing new flavors and prolonging shelf life.

II.1.Definition:

Preserved egg, also known as pidan, thousand-year egg, or century egg, has been an alkaline-fermented ethnic food in China for many generations. It represents a unique example of alkaline fermentation, achieved through alkaline treatment rather than the use of microorganisms. Sodium hydroxide (NaOH) is produced from the reaction of sodium carbonate (Na2CO3), water (H2O), and calcium oxide (CaO) present in the pickle or coating mud. This solution penetrates the eggs, inducing physicochemical changes, color alterations, and gelation. As a result, the egg white becomes semitransparent with a tea-brown color, while the yolk transforms into a solid or semisolid state, featuring a dark-green hue. This procedure enables a longer shelf life and depending on the processing methods, various types of pidan are available, including pine-floral pidan, soft-yolk pidan, and hard-yolk pidan **(Wang and Fung, 1996).**

II. 2.History:

Century Eggs origin dates back to the Ming Dynasty (1368-1644) in China although the identity of the inventor remains a mystery. There exist two folk legends in the region of Yiyang in Hunan renowned for its production of high-quality that narrate the supposed invention of century eggs during the Ming Dynasty but it is unverified. It is widely believed that the initial preservation of eggs served as a practical solution for ensuring a stable egg supply during times of scarcity. Farmers and households stumbled upon a method to achieve this by encasing eggs in a mixture composed of clay, ash, quicklime, salt, and rice straw. This clever technique allowed eggs to be stored for several months. Over time, the preservation process underwent refinement, gradually transforming Century Eggs into a revered delicacy within Chinese communities.

In the historical record, the earliest documented mention of Century Eggs can be found in the "Miscellany of Bamboo-island Workshop" (竹屿山房杂部), which was completed in the 17th year of Emperor Hongzhi's reign during the Ming Dynasty in 1504. This text delves into one of the earliest versions of Century Eggs known as the "Hun Dun Zi" (混沌子).

As the Ming dynasty neared its end, variations in preservation method emerged, with different types of ashes being employed. This evolution is documented in Dai Xi's book "Yangyu yueling" (养余月令), in which chestnut ash was introduced as a novel ingredient in the process.

Later in the early Qing Dynasty (1644-1911), the philosopher and scientist Fang Yizhi (1611–1671), hailing from Tongcheng in present-day Anhui Province, referred to Century Eggs as "Transformed eggs" in his work "Little Knowledge of Physics" (物理小识). He described the production process and proposed that the use of various types of charcoal ash led to distinct chemical alterations within the eggs, resulting in distinct products, and he was convinced that these "transformed eggs" had evolved from the salted duck eggs documented in "Essential Techniques for the Welfare of the People" (齐民要术); China's believed first agricultural encyclopedia authored by Jia Sixie, a renowned agronomist during the Northern Wei Dynasty (AD 386-534).

By the end of the Qing Dynasty, the method of making Century Eggs became more thoroughly documented in various literary works, resulting in the standardization of ingredient proportions. Typically, duck eggs were preserved using a specific ratio of salt and ash. The process involved wetting the eggs with a thick rice soup, coating them in the ash-salt mixture, and subsequently allowing them to cool before being placed in storage jars. After an approximate duration of around twenty days, the Century Eggs were considered fully prepared.

In the 1980s, China introduced low-lead and lead-free century eggs in response to the discovery that high lead content posed health risks. In summary, century eggs boast a rich history and have undergone continuous evolution, with different regions and individuals playing pivotal roles in their development and enhancement and today, they have become a common delicacy in everyday life, as well as a staple at banquets. Their popularity extends beyond China, with pidan being exported to other Asian countries like Malaysia, South Korea, Japan and other Chinese migrated countries. More recently, exports to the US and Canada have seen a significant rise, driven by their growing Chinese populations.**(The historical origins of Chinese preserved egg ,Ministry of agricultural and rural affair of the people’s republic of china retrieved on 05/02/2024 website http://www.agri.cn/)**

III. Processing methods and the chemical changes during processing

Duck eggs are the preferred choice for making preserved eggs, not only due to their consumption accounting for approximately 30% of total egg consumption in countries like China and Southeast Asia, but also because of their characteristic flavor and aroma derived from the yolk. However, preserved eggs can also be made from chicken eggs and other types of eggs. **(Ganesan and Benjakul, 2011a, 2011b)**

III.1.Pocessing methods

III.1.1.Traditional methods:

III.3.1.Coating Method:

This traditional process begins by creating a muddy paste containing all the coating ingredients required for pidan production. This involves mixing salt, lime, and sodium carbonate, then adding liquid tea and ash grass. The mixture is pounded until it forms a paste. Set aside overnight to allow time for the chemical reaction to take place (**hunger and technology egg preservation in china 1981**). The paste is then used to completely coat already cleaned fresh duck eggs before rolling them in rice hulls to prevent sticking together. These coated eggs are placed in sealed jars for fermentation, 40 days in the summer and 50 days in the winter. The sealing step is crucial for producing a high-quality product. A well-sealed jar prevents the mud coating from drying out, as reported by Wang and Fang (1996).

III.3.2.Immersion method:

In this method, all of the ingredients are mixed into a curing solution. This solution is created by adding water to a vessel containing a mixture of sodium carbonate, lime, table salt, and lead oxide, while continuously stirring. Once the mixture cools, eggs are immersed for 45 days at 20-25°C. After completing the curing process, the eggs are removed, washed with water, and left to air dry. Next, the eggs are coated with liquid paraffin before being packaged and marketed. Ginger and cinnamon can be added to the pickling solution to reduce the pungent taste. (**Wang and Fang 1996**).

III.3.3.Rolling powder method:

The eggs are coated with a thin layer of mud paste and rolled in the rolling powder, in which all the ingredients have been included, before being packed and sealed in the jar. The powder-rolled eggs are allowed to ferment for 20-30 days at room temperature. The ingredients used for the rolling powder method vary slightly according to the season. The rolling powder method produces hard yolk pidan. The advantages of this method are its low cost and ease in handling. **(Palanivel Ganesan, Chemical Compositions and Properties of Alkali Pickled Egg (Pidan) as Affected by Cations and Selected Pickling Ingredients. Thesis of doctor of philosophy in food science and technology Prince of Songkla University 2010)**

Tableau 2 Ingredients for rolling, coating and immersion method Source: Wang and Fung. (1996) and Li and Hsieh (2004)

Ingredient	Rolling		Coating	Immersion
	Amount (Kg)			
	Spring and Fall	Summer	Summer	Summer
Na_2CO_3	1.5	1.5	10	3.6
CaO	3.8-4.2	4.5-5.5	25	14
PbO	-	-	0.45	0.37
Salt	1.4	1.4	4	2
Tea	0.1	0.1	-	1.5
Water	3	3	50	50
Yellow earth	2	2	-	-
Dry mud	-	-	25	0.5
Wood ash	-	-	25	1

III.1.2. Modern methods:

Currently, pidan (century eggs) are produced using a variation of the immersion method. Instead of the traditional ingredients, we now use food-grade sodium hydroxide, salt, and small quantities of non-lead metal ions, such as zinc chloride ($ZnCl_2$).**(Zheng et al.,2022 A review on the development of pickled eggs: rapid pickling and quality optimization)**

III.2.The chemical changes during the processing:

After mixing the ingredients to make pidan, several chemical reactions occur:

CaO + H2O → Ca(OH)2

Ca(OH)2 + Na2CO3→ 2NaOH + CaCO3

Na2O3 + H2O → 2NaOH + O2

K2O + H2O → 2KOH

(Na2CO3 and K2O are from the plant ash.)

The NaOH diffuses through the eggshell pores, causing changes in osmotic pressure and leading to the denaturation and hydrolysis of egg proteins into polypeptides and, eventually, amino acids (Blunt and Wang, 1918). The best pidan product is achieved when the NaOH concentration is maintained between 3.6% and 4.6%. If the NaOH concentration is lower than 1.6%, the egg protein does not coagulate, resulting in a product that is not pidan. The ideal processing temperature ranges from 20°C to 30°C, with higher temperatures reducing the processing time.

Maillards reactions between the glucose in the albumen and amino acids, along with pigments from tea, impart the brown color to the albumen gel **(Wang and Fung, 1996).** Amino acids produced from protein decomposition, such as cysteine, are continuously converted into ammonia and hydrogen sulfide H2S. The hydrogen sulfide then reacts with iron in the yolk, giving it its characteristic dark-green color.

These chemical interactions are crucial for the maturation process, contributing to the unique appearance and flavor of pidan **(Wang and Fung, 1996).**

IV. Maturation mechanism of preserved egg :

Currently, preserved eggs are made using alkaline liquids and as they penetrate the eggs, the proteins undergo hydrolysis, resulting in the formation of gels; characteristic of the preserved eggs. These gels form due to numerous interactions between proteins and between proteins and solvent molecules

IV.1. Egg white gel formation:

Research indicates that ovalbumin and other proteins present in the egg white undergo complete denaturation due to the diffusion of alkali within the egg. This maturation process progresses through various stages. In the initial stage of formation, proteins experience denaturation, while their primary and secondary structures remain intact. The free water content in fresh egg whites gradually increases, leading to a dilution of the viscous egg white. During the solidification stage, the secondary protein structures are compromised as hydrogen bonds break and disulfide bonds form, as reported by (**Zhao et al. (2016b**)). Free water transitions back to bound water, binding with protein molecules to create a transparent elastic colloid. In the phase of color change, the primary structures of the proteins are destroyed, and simultaneously, the Maillard reaction takes place, resulting in a gradual color shift from yellow to brown. The final stage of maturation involves the complete denaturation of proteins, resulting in gels that become entirely dark brown while retaining a certain degree of elasticity.**(Ma et al., 2006).**

The microstructure of mature preserved egg white gels shows that it is a fine three-dimensional gel network interwoven with a loose linear fibrous mesh structure, and the mesh structure becomes more regular, finer, and compact with the alkali treatment time. Moreover, the egg white gels are maintained by numerous ionic bonds (85%), a few disulfide bonds (5%), and very few hydrophobic interactions and hydrogen bonds.**(Chen et al., 2015; Zhao et al., 2016).**

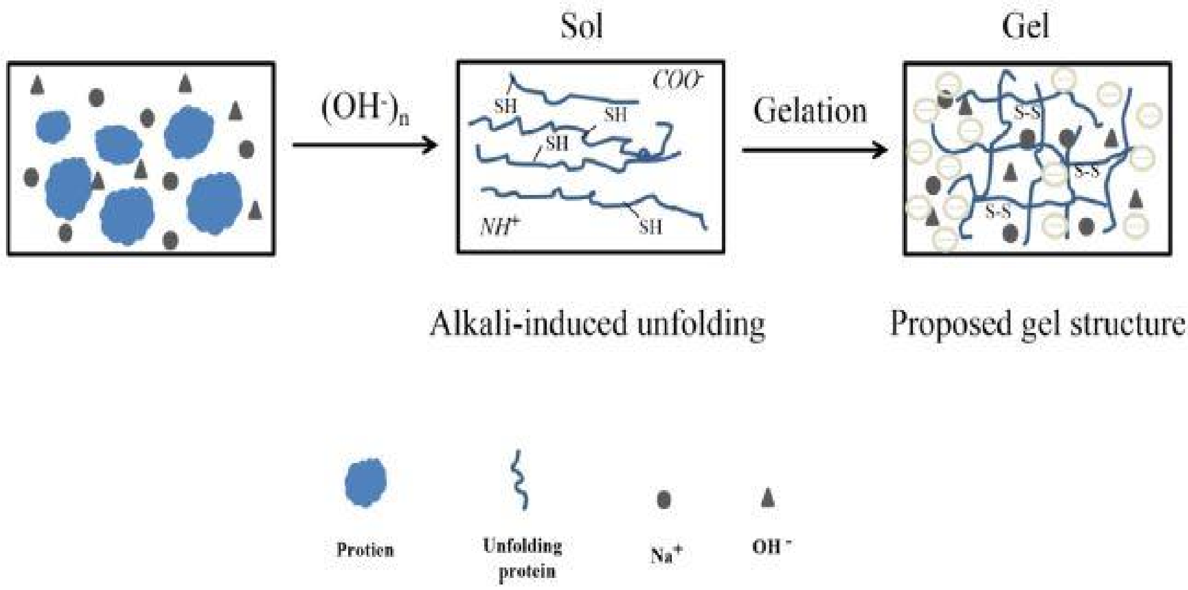

Figure 2 A schematic of the formation mechanism of preserved egg white gel induced by strong alkali (Zheng et al.,2022 A review on the development of pickled eggs: rapid pickling and quality optimization)

IV.2. The coagulation of egg yolk

The coagulation of egg yolks initiates from the exterior and progresses towards the interior. Initially, the exterior egg yolks solidify, while the interior becomes viscous. As the pickling time extends, the sol range gradually diminishes. LDLs and HDLs, the most abundant proteins in egg yolks, exhibit distinct gelation behavior in an alkaline environment, playing a pivotal role in the aggregation behavior of the entire egg yolk. Under strong alkali conditions, the secondary structure and peptide chains of LDLs undergo changes, resulting in the formation of unknown proteins through ionic bonds, hydrophobic interactions, and disulfide bonds. LDLs form gels wherein proteins and lipids bind, retaining abundant water. Conversely, HDLs experience extensive unfolding and reorganization, forming a network structure with high thermal stability and uniform density supported by ionic and disulfide bonds. This process increases the hardness of the entire egg yolk gels. **(Yang et al.,2020a,2020b).** As yolks solidify, their color gradually deepens. Sulfur-containing amino acids in egg yolk proteins degrade under strong alkaline conditions, producing sulfur ions (S2). These ions reduce the ferric iron(Fe3+) of phosvitin in egg yolks to ferrous iron (Fe2+), and forming ferrous sulfide (FeS). The resulting product is a characteristic blue-green hue, that combines with the inherent yellow pigment in the yolk turning into a yellow-green or dark green coloration. **(Li et al., 1992).**

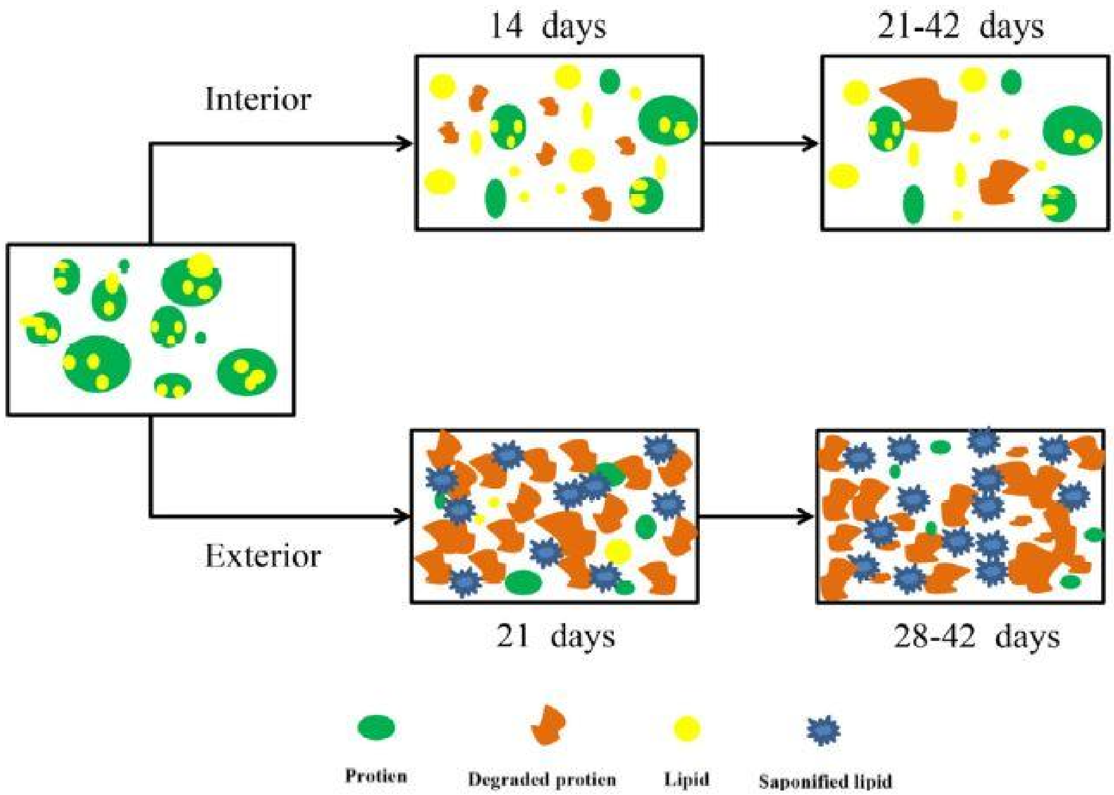

Figure 3 A schematic of the gelation behavior of internal and external egg yolk under strong alkali treatment. (Zheng et al.,2022 A review on the development of pickled eggs: rapid pickling and quality optimization)

IV.3. Maillard reactions

The Maillard reaction is responsible for the brown color of the egg white; it is a non-enzymatic browning process that involves the interaction between the carbonyl group of reducing carbohydrates and the amino group of free amino acids, as well as lysyl residues in proteins. This reaction occurs in three major stages **(Ajandouz et al., 2001).**

Initially, the carbonyl group of a reducing sugar reacts with the amino group of an amino acid to produce a glycosylamine. This step is pH-dependent and often occurs at higher temperatures. The glycosylamine then undergoes a rearrangement to form a ketosamine, known as the Amadori rearrangement. The reactions continue with the dehydration and fragmentation of the ketosamine, creating a variety of intermediate compounds such as reductones and dehydroreductones. These intermediates eventually produce Advanced Glycation End-products (AGEs), complex molecules that contribute to the brown color and rich flavors typical of Maillard reaction products.

IV.4.Factors affecting maillard reaction :

Many factors are involved in the development of brown color mediated by the maillard reaction such as :

IV.4.1.Sugars:

Reducing sugars are crucial elements in the Maillard reaction, providing the carbonyl groups that interact with the free amino groups of amino acids. Additionally, starch and non-reducing sugars can contribute carbonyl groups after hydrolysis. **(Camire et al., 1990).**

IV.4.2.Amino acids:

The reactivity of amino acids in forming Maillard reaction products varies depending on their type and concentration. The rate of conversion is also influenced by the chain length of peptides or proteins.

IV.4.3.pH:

The Maillard reaction can occur in both acidic and alkaline environments, but it is more favorable under alkaline conditions. In alkaline conditions, amino groups take an active form, and sugars are in their reducing form (**Van Boekel, 2001).**

IV.4.4.Temperature:

An increase in temperature generally accelerates the rate of chemical reactions. At low temperatures (20-60°C), the Maillard reaction proceeds more slowly than at higher temperatures (100-150°C). Temperature is also a critical parameter that affects the aroma characteristics and flavor of foods, as mediated by Maillard reaction products (MRPs).

IV.5.The effect of Sodium hydroxide concentration on maturation mechanism:

During the pickling process, if the concentration of NaOH is high, the yolks become harder, and the liquefaction and hydrolysis of the egg white are observed **(Ganasen and Benjakul, 2010, 2011, 2014)**. This results from the rapid denaturation of the aggregated proteins that form white gels due to the high alkali concentration and the continuous penetration of lye breaking the disulfide bond that stabilize the gels. This phenomenon is called alkali liquefaction **(Gao et al., 2020)**

Heavy metal compounds are utilized to regulate the penetration of alkaline, they form insoluble sulfides that plug the eggshell stomata and prevent excessive alkali damage to the egg white gels, and inhibit the liquefaction phenomenon during the pickling process **(Yan and Zhu, 2006; Tu et**

al., 2012). Hence, the regulation of NaOH penetration is crucial in the processing of preserved eggs. The rate of penetration is affected by concentration, temperature, type and content of heavy metal ions, and the concentration of other additives, all directly or indirectly affecting the quality of pidan.

IV.6. Comparison between fresh egg and pidan shelf life

Fresh Eggs

1. **Unrefrigerated:**
   - Shelf Life: About 2 weeks.
   - Storage Conditions: Room temperature (around 20°C or 68°F).
2. **Refrigerated:**
   - Shelf Life: 3 to 5 weeks beyond the "sell-by" or expiration date on the carton.
   - Storage Conditions: Refrigerated at about 4°C or 39°F.

Pidan (Century Eggs)

1. **Unopened:**
   - Shelf Life: 1 to 3 months beyond the expiration date.
   - Storage Conditions: Refrigerated at around 4°C or 39°F.
   - Considerations: Unopened pidan eggs should be kept in their packaging or an airtight container to prevent moisture loss and odor absorption. Their long shelf life is due to the preservation process that stabilizes the egg.
2. **Opened:**
   - Shelf Life: 3 to 7 days.
   - Storage Conditions: Refrigerated at around 4°C or 39°F.
   - Considerations: Once opened, pidan eggs should be consumed relatively quickly. They should be stored in an airtight container to maintain their quality and prevent the absorption of other odors from the refrigerator.

Comparison Summary

While fresh eggs have a shorter shelf life, especially when not refrigerated, pidan eggs, due to their preservation process, can last significantly longer when stored properly. However, like fresh eggs, once opened, pidan eggs should be consumed relatively quickly to maintain their optimal taste and texture. The extended shelf life of pidan eggs is a result of the pickling and fermentation process they undergo, which helps to preserve the eggs and prevent spoilage. This makes pidan eggs a more shelf-stable option compared to their fresh counterparts, potentially reducing food waste and providing consumers with a longer-lasting egg product. It is important to note that proper storage conditions, such as refrigeration, are crucial for maintaining the quality and safety of both fresh and pidan eggs. By understanding the differences in shelf life, consumers can make informed decisions about which egg product best suits their needs and storage capabilities.

V. The nutritional value of pidan;

Pidan is rich in proteins, lipids, and minerals. A whole pidan egg contains 13.1% protein, 10.7% fat, 2.2% carbohydrates, and 2.3% ash. In comparison, a fresh duck egg contains 9.30-11.80% protein, 11.40-13.52% fat, 1.50-1.74% carbohydrates, and 1.10-1.17% ash. This demonstrates that pickling technology significantly affects the nutritive value of pidan.

Tableau 3 Nutritive composition of Fresh duck egg and pidan (Comparative Study on the Nutritional Value of Pidan and Salted Duck Egg P. Ganesan , T. Kaewmanee1 et al)

Sample	Composition (wet wt %)					Source
	Proteins	Fat	Carbohydrates	Ash	Salt	
Fresh duck egg	9.30-11.80	11.40-13.52	1.50-1.74	1.10-1.17	0.33	Kaewmanee et al. (2013) Lai et al. (2010)
Pidan	13.1	10.7	2.2	2.3	Not reported	Ganesan and Benjakul (2013)

V.1. Proteins and amino acids in pidan white

Proteins decrease during the pidan pickling process due to alkali migration in the egg white, causing degradation and aggregation of proteins. Additionally, the Maillard reaction and racemization lead to the loss of amino acids, reducing overall protein content. This phenomenon can be mitigated by adding amino acids or cations to the pickling solution (**Chang et al., 1999a; Chang et al., 1999b)**. The process can result in either an increase or decrease in amino acid levels, certain amino acids, such as leucine, asparagine, and glutamine, are synthesized during pidan making, increasing their concentration. In contrast, lysine, serine, and threonine are lost during the process.

V.2.Proteins and amino acids in pidan yolk

Yolk proteins exist as lipoproteins, commonly referred to as low-density lipoproteins (LDL) or high-density lipoproteins (HDL). Alkaline treatment causes significant degradation of yolk proteins, resulting in the production of many peptides and amino acids. During extensive alkaline treatment, leucine, asparagine, and glutamine are found in higher concentrations in the pidan yolk **(Ganesan and Benjakul, 2010a, 2010b).**

Tableau 4 Amino acid contents of white and yolk of fresh egg and pidan (expressed as residues/1000 residues) (Comparative Study on the Nutritional Value of Pidan and Salted Duck Egg P. Ganesan , T. Kaewmanee1 et al)

	Fresh duck egg		Pidan (ZnCl treated)	
Amino acids	Egg white	Yolk	Egg white	Yolk
Asparagine	91	89	91	93
Threonine*	67	60	65	63
Serine	97	99	90	86
Glutamine	123	110	124	114
Glycine	61	54	62	59
Alanine	68	77	70	78
Cysteine	1	4	2	4
Valine*	70	64	74	67
Methionine*	54	26	55	30
Isoleucine*	41	50	44	49
Leucine*	81	86	83	88
Tyrosine	33	34	33	35
Phenylalanine*	58	36	59	39
Hydroxylysine	0	0	16	12
Lysine*	61	70	42	58
Histidine*	17	37	21	29
Arginine	6	5	5	6
Tryptophan*	33	52	24	45
Hydroxyproline	0	0	0	0
proline	37	45	40	47

V.3.Minerals content of pidan:

Both the white and yolk of pidan are excellent sources of minerals. However the mineral content is influenced by the pickling methods and minerals used in the process. During pickling, the sodium concentration increases in the white, while the salt content in the yolk decreases due to high lipid aggregation that impedes ion exchange. Additionally, sulfur content is reduced during the alkaline process.

Other ions, such as lead or zinc, may be present in the pidan if they are included in the pickling solution.

Tableau 5 Mineral composition of fresh egg and pidan (Comparative Study on the Nutritional Value of Pidan and Salted Duck Egg P. Ganesan , T. Kaewmanee1 et al)

Parameter	Fresh egg	Pidan (ZnCl treatment)
Ca	181.34	337.04
Mg	98.12	54.11
Na	826.3	3767.71
K	735.82	995.27
Zn	3.95	6.38
Cu	0.93	0.69
Fe	9.62	8.82
N	17.77	17.99

V.4. Lipid and fatty acid composition of Pidan

The process of making pidan eggs significantly affects their lipid and fatty acid content. It has been found that the content decreases due to alkali penetration, which results in the saponification of yolk lipids. Pidan eggs have a lower concentration of phospholipids and cholesterol compared to fresh eggs, making them a good alternative for low-cholesterol egg products while still containing an abundant amount of other essential fatty acids and lipids.

Tableau 6 Lipid composition of Pidan yolk (Liu et al.2005)

Composition (%)	Fresh duck egg	Pidan
Phospholipids	350.5	175.1
Cholesterol	38.15	28.51

Experimental section

I. Objective

Our objective was to preserve eggs using the traditional Chinese method of pickling them in an alkaline solution, resulting in the distinctive product known as pidan. We aimed to evaluate the entire process of making pidan and to assess the changes in the organoleptic characteristics of the eggs at the end of the process.

1. Workplace

We carried out this project at the Higher National Veterinary School (ENSV) in Algiers.

2. Duration of the Study

This study was conducted from May to June.

II. Part one: Making Pidan

II.1.Materiel

- Scale
- Plastic wrap
- Plastic container with lid

For the solution:

- Sodium hydroxide (NaOH) 42g
- Salt (NaCl - sodium chloride) 72g
- 1 liter of water
- Chicken egg

Figure 4 The materiel use in the experiment

II.2.Method

a. Preparation of the pickling solution:

- We start by measuring out 42g of NaOH (sodium hydroxide, caustic soda) and 72g of salt (NaCl).
- We dissolve the salt and caustic soda completely in water over gentle heat, bringing the solution to a boil.
- After boiling, we let the solution cool down before moving on to the next step.

b. Brining Eggs

- We start by thoroughly cleaning the eggs and placing them in a clean plastic container.
- We finish by pouring the cooled solution over the eggs, ensuring they are completely covered.
- Finally, we store it at room temperature (15-20°C) for 10 days.

Figure 5 covering eggs with the pickling solution and storing them (Personal picture)

c. Removing from brine

- We carefully remove the eggs from the brine solution after approximately 10 days.
- We rinse the eggs thoroughly to remove any remaining brine and allow them to dry naturally.
- Then, we proceed to wrap each egg in several layers of transparent plastic film to prevent oxygen exposure.
- Finally, we leave the wrapped eggs to mature in this state for about 2 weeks.

Figure 6 Eggs wrapped in transparent plastic film (Personal picture)

After approximately a month from starting this procedure, the eggs are ready for use. We can crack them open to reveal the final product: Pidan.

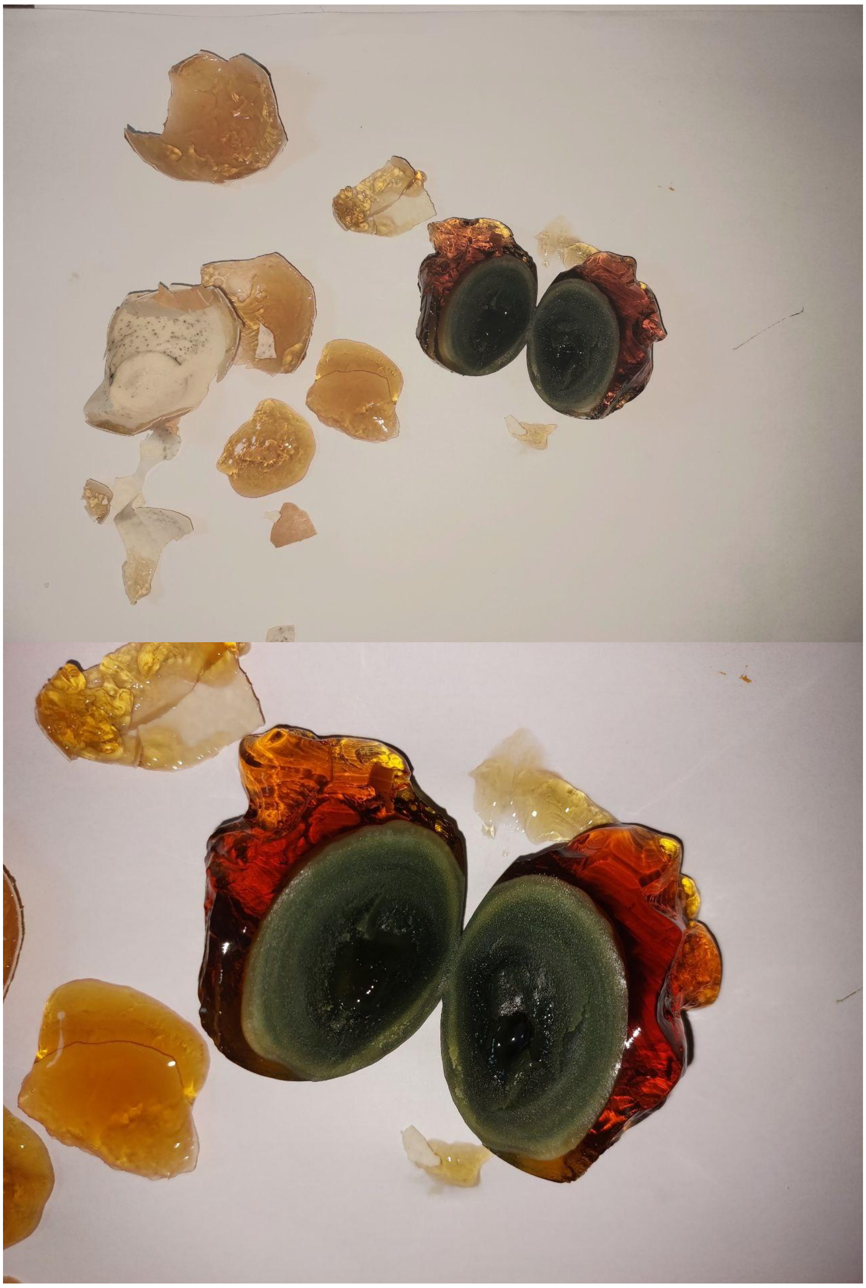

Figure 7 Ready Pidan egg (Personal picture)

III. Results and discussion:

Our results were consistent with the expected changes and the information previously mentioned in the bibliographic section. The pickling of eggs using an alkaline solution caused changes on different levels:

1. Appearance and Texture:

Pidan is also known for its striking appearance, which is a result of the unique preservation process it undergoes. The transformation of the egg is visually remarkable:

Egg white:
After the pickling duration, the egg white color turned to a transparent brown, with the consistency changing to a gelatinous texture sticking to the shell when the eggs were opened. These changes were observed in the absence of any form of heat treatment after 25 days of pickling. As mentioned previously, the egg white proteins undergo denaturation due to the penetration of alkali inside the egg, giving them a transparent, elastic colloid that later gains the brown color through the Maillard reaction.

Egg Yolk:

After 25 days of pickling in an alkaline solution, the egg yolk underwent significant changes in both color and texture. The yolk turned a dark green color, and its outer layer developed into a solid, firm texture. This transformation contrasts with the inner portion of the yolk, which remained liquid to creamy, retaining a softer, more viscous consistency. These changes are indicative of the chemical interactions between the yolk components and the alkaline solution. In particular, the proteins, especially HDL and LDL, undergo denaturation and structural changes, leading to the coagulation of the yolk, as stated in previous research on this maturation process.

Figure 8 century egg sliced open (found online by Kowloonese)

2. Flavor Profile:

The fermentation and preservation process of pidan results in its strong and distinctive flavor. This unique taste arises from the breakdown of proteins and fats into amino acids and other flavor compounds through the Maillard reaction. Additionally, the salt in the preservation mixture imparts a mild saltiness, complementing the overall flavor profile. A hint of ammonia, a hallmark of pidan, is also present, produced during the alkaline treatment. This ammonia flavor can become more pronounced with longer preservation durations, contributing to the egg's characteristic taste.

3. Aroma:

Following the preservation process, pidan eggs develop a strong and distinctive aroma that is characteristic of this traditional delicacy. This aroma can be off-putting to many people who are unaccustomed to it. The primary contributor to this repugnant smell is the ammonia produced during the maturation process. As the egg ages and undergoes curing, the chemical reactions result in the release of ammonia, which is largely responsible for the pungent aroma.

While the strong aroma of pidan eggs may be a hurdle for those unfamiliar with this traditional food, it is highly appreciated by those who have developed a taste for this unique delicacy. With time and gradual exposure, many people will be able to acclimate to the distinctive smell and come to appreciate the nuanced flavors and textures that pidan eggs offer.

4. Maturation and Aging :

The aging process is a lengthy and intricate procedure that can take several weeks to months to complete. The duration of the process depends on various factors, including temperature, season, and the specific method employed.

Traditional Methods:

Traditional methods of aging pidan eggs involve a labor-intensive process, particularly when it comes to coating each individual egg. The ingredients used in this process can significantly impact the intensity and complexity of the final flavor profile.

Modern Methods:

In contrast, modern methods, such as the one utilized in this project, rely on carefully controlling the concentration of alkali and salt. Achieving the right balance is crucial for producing a high-quality pidan egg. If the concentration of these compounds is too low, the final product will not meet the criteria for a true pidan egg. Conversely, if the concentration is too high, it can lead to the undesirable liquefaction of the egg white.

Despite the relative simplicity of the process, aging pidan eggs requires a minimum of 25 days and meticulous attention at each stage. This is especially true when handling strong bases like sodium hydroxide, which are commonly used in the curing process. Proper safety precautions and handling techniques are essential to ensure the success of the project and the safety of those involved.

In summary, while the aging process of pidan eggs may seem straightforward, it demands a significant investment of time and careful monitoring to achieve the desired results. By understanding the factors that influence the process and following best practices, it is possible to create a high-quality pidan egg that showcases the unique flavors and textures associated with this traditional delicacy.

IV. Conclusion

The rising population and growing demand for eggs in Algeria present an opportunity for century eggs, or pidan, to emerge as a novel and appealing product. These preserved eggs offer a distinctive flavor and texture that can captivate adventurous consumers seeking new culinary experiences. Moreover, when properly pickled and cured, century eggs boast an extended shelf life, contributing to overall food security. Beyond their practical benefits, pidan eggs are remarkably versatile, capable of enhancing a wide range of dishes by imparting depth, complexity, and unique flavors that can elevate the culinary experience. With their unique sensory qualities, practical advantages, and versatility in the kitchen, century eggs hold the potential to carve out a niche in the Algerian market.

However, pidan eggs are not without their challenges. One significant weakness is the complex and labor-intensive production process, which can vary depending on the specific method employed. This complexity may hinder the ability to scale up production and meet growing demand efficiently. Additionally, pidan eggs face an uphill battle in becoming a customer favorite due to their strong, distinctive flavor and ammonia-like aroma, which can be off-putting to consumers unfamiliar with this traditional delicacy. The striking appearance of pidan eggs, with their dark, mottled shells and gelatinous, translucent whites, may also contribute to misconceptions and stereotypes that could limit their appeal in the broader market.

Therefore, a strong marketing and promotional plan is crucial for the success of pidan in areas new to this product. By positioning it as a nutritious and unique food appealing to health-conscious consumers and educating people on its cultural significance, we can increase its acceptance and popularity, while still adhering to food safety regulations.

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