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A REVIEW ON UNDERSTANDING OF EGG YOLK AS FUNCTIONAL INGREDIENTS

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ABSTRACT

The various bakery products like cake, cookies, and bread includes egg as an ingredient, which plays significant role in the product development. The egg yolk is the dense yellow part of the egg and is considered nutritionally more beneficial when compared to the other portion of the (egg whites). The egg yolk is considered a rich source of essential fat-soluble vitamins (A, D, E, and K) and few water-soluble vitamins (B_6, B_{12}). It is also rich in calcium, magnesium, iron, and selenium. This review discusses about functional characterization like interfacial properties, gelation, and phase separation behavior of egg yolk and its constituents (plasma and granules). This reviews briefly discuss about constituent characterization like xanthophylls, color stability, fatty composition with using newer analysis techniques. Besides, its applications in different industries like bakery, snacks, meat industry and production of nanogels have also been documented.

Keywords: Egg yolk, phosvitins, lipovitellins, yolk granules, yolk plasma

INTRODUCTION

From the last 60 years, egg industry is in evolution trend due to changes in the technology of egg processing with producing different products. Froning, (2008) reported the consumption of egg in the formed of processed products has been increased. Recently, the food industry along with the biotechnological area has been focus on the egg yolk as ingredient having nutritional significance which were previously ignored due to saturated fat and dietary cholesterol which increases the cholesterol level in the body and makes it prone to heart diseases (**Laca et al., 2015**). Till the date, there is no evidences or research supports that the risk for cardiovascular disease (CVD) is due to the consumption of dietary cholesterol. Americans diet restricted dietary cholesterol to 300 mg/day which removed the recommendation for 2015–2020 by Dietary Guidelines for Americans (**Soliman, 2018**). This review gives insights on nutritional, functional characteristics of egg yolk with its application and characterization.

NUTRITIONAL SIGNIFICANCE OF EGG YOLK

The egg yolk is a type of oil-in-water emulsion, divided in two parts in which one part called as plasma (aqueous phase) and granules (0.3µm–2 mm insoluble denser structures) (**Guilmineau & Kulozik, 2006**), which composed with 52%dry matter (in which 65% fat, 31% protein and 4% carbohydrates, vitamins and minerals) (**Guilmineau et al., 2005**). The yellow part of an egg is a capsule which carry essential nutrients like vitamin (B_6, B_{12}, A, D, E, and K) and rich source of minerals (calcium, magnesium, iron, and selenium). The yolk also contained carotenoids which gives yellowish color, and act as antioxidants which helps in improving the vision (**Huizen, 2017**). It also shows anti-inflammatory due to presence of water-soluble vitamin (choline) present in the egg yolk and helps in regulation of cardiovascular function of the body (**Huizen, 2017**).
The important proteins present in the egg yolk mainly include phosvitins and lipovitellins. The phosvitins are the most phosphorylated proteins, they are important for embryo development and act by sequestering iron, calcium and other cations. Lipovitellins are mainly involved in the storage of metals and lipids, they also contain a heterogeneous mixture of about 16% (w/w) non-covalently bound lipid.

FUNCTIONAL CHARACTERIZATION OF EGG YOLK

The functional characterization of the egg yolk delivers information about the physicochemical and interfacial properties, aggregation behavior, foaming, swelling and hydration, and phase separation behavior.

Interfacial and physicochemical properties

A good emulsifying properties and organoleptic characteristics are also observed with egg yolk reported by **Anton and Gandemer (1997)**. These emulsion or foam formation capacity and stability were influence with physicochemical properties like surface hydrophobicity and solubility of proteins and also the processing parameter like composition, and temperature etc. (**Bovskova & Mikova, 2011**). **Li et al. (2018)** found that the interfacial properties like emulsifying and foaming are corelated with the physicochemical properties such as surface tension, zeta potential, and particle size of egg yolk can be influence with NaCl concentration and pH, in various processing application like egg derived aerated products/emulsified sauces. The zeta potential of egg yolk decreases as increase in pH from 6.0 to 10 (**Li et al., 2018**) due to the α-livetin protein which is present in the yolk get solubilize as pH increases (**Nilsson et al., 2006**). The interfacial properties like emulsifying and foaming properties influence due to the particle size of proteins (**Morales et al., 2015**). **Li et al. (2018)** reported that foam formation by egg yolk destabilizes due to the decrease in the surface tension and because of extra charge which corresponds to concentration of NaCl ≥ 0.6% and pH > 7.0. Author also observed that continuous dispersion of egg yolk upto pH 10 produces stabilized emulsifying activity due to reduction of particle size continuously, and also at concentration of NaCl > 1.8%, started falling with the slow reduction amplitude of particle size which dominates the emulsifying stability index of egg yolk dispersions. **Zhu and Damodaran,** (1994) reported that breaking effect of cohesive viscoelastic film by salt ion which results in foam expansion power and foam stability of egg white/yolk solutions at high NaCl contents. **Castellani, et al. (2005)** observed the content of phosvitin in egg yolk which used for the preparation of emulsion was influenced at high concentration of salt. Other physical properties like protein solubility and surface hydrophobicity also effect on the emulsifying properties of egg yolk.
Due to the good quality of foaming characteristics of egg white protein, widely used in the bakery industries, but a tiny traces of egg yolk influences the foaming capacity which alters the quality of bakery products (**Wang & Wang, 2009**). These yolk contaminations considered as major factor which difficult to avoid in egg white with advance technology of breaking and cracking (**Liu et al., 2014**). **Li et al. (2019)** studied the influence of different proportions of egg yolk fractions and egg yolk on foaming characteristics such as foam microstructure, foam ability, and foam ability. The low concentration of plasma and granular yolk faction shows better foam abilities as compared to egg yolk in foaming characteristics of egg white-yolk fractions dispersions. The poor foaming properties of egg white contaminated with egg yolk is due to the plasma and go ód foaming stability is observed due to the granules for the dispersions.

Gelation/aggregation behavior

The enhancement in the quality of food like texture and shape is due to the improvement in the gel formation which is an imperative functional characteristic of egg yolk proteins, which results in the increasing the viscosity and water holding capacity, also maintain fat and stickiness (**Martin et al., 2016**). The various food processing like freezing and heating plays significant roles in the protein gelation behavior which results in gel formation in egg yolk (**Au et al., 2015**). **Xu et al. (2018)** investigate the gelling behavior of egg yolk (raw as well as cooked) during the pickling process. Author observed the gelling behavior in egg yolk during pickling period of 21 days which occurred in two stages in high-salt treatment with or without heating. At 21st day of salting in first stage, granules of raw egg yolks destroyed partially and decreased slowly which results in hardened texture with reduced soluble protein content and rise in free sulfhydryl content. In second stage from the period of 28 to 35days of salting shows destruction of particle which contributes in gel formation. In these stages, the hydrophobic sites of proteins expose for unfolding interactions, which results to reduce sulfhydryl content with increasing hydrogen bonding and disulfide bonds formation.
But in case of cooked salted eggs during first stage (0-21 days) lipid granules and protein decreases slowly, but there is formation of a dense gel network structure. The gel formation is resulted due to the reduction in alpha helix which results in reduction of protons of lipids and water. In second stage, there is rearrangement of lipids and proteins, which results in aggregate due to hydrophobic interactions (interactions between protein molecules and interactions between proteins and lipids) (**Xu et al., 2018**).

Phase separation behavior

Many techniques like ultracentrifugation, egg yolk fractionation by dialysis, dilution, and ammonium sulfate precipitation are used to isolate low density lipoproteins (LDL), which results in the lower yield (**Moussa et al., 2002**). **Navidghasemizad et al. (2015)** studied the phase separation behavior by using anionic polysaccharides like carrageenan, gum arabic, and xanthan gum with different pH (3, 5, 6, 8, and 10) of egg yolk. These studies suggested that pH and polysaccharide nature play a significant role in interaction with egg yolk which results in phase separation. In general, two-fold diluted egg yolks separate in two phase granules and plasma. But the suspension of (carrageenan, gum Arabic) polysaccharide/yolk formed either a biphasic or a monophasic system at pH 6 and 0.4% concentration of polysaccharide. In case of xanthan gum yolk suspension employed the triphasic separation at pH 6 in which at the top layer formed with cream which account for 72% of lipid on dry basis, middle layer is aqueous phase and pellets are formed at the bottom, For example fig 1. shows that phase separation in terms of triphasic and biphasic separation.

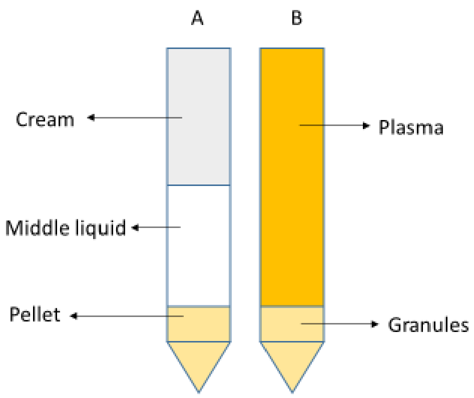

Figure 1 Egg yolk phase separation a) triphasic separation (b) biphasic separation (Modified fig of Navidghasemizad et al., 2015)

The observation of phase separation concluded the hydrophobic and electrostatic interactions between xanthan gum and rheological properties xanthan gum of could be responsible for the unique phase separation (**Navidghasemizad et al., 2015**). The hydrophobic interactions with polysaccharides are due to the presence of weak hydrophobic groups in plasma lipoproteins (**Goodman & Shafrir, 1959**). Hence, LDL composed with hydrophobic amino acids i.e around in 40% and some lipid on the surface of LDL which react with hydrophobic cavities generated by hydrophobicpyruvate chains of xanthan gum (**Anton et al., 2003; Tsutsui & Obara, 1982; Jouquand et al., 2008**). **Kozarac et al. (2000)** also suggested the possibility of phospholipids present on the surface of lipid could react with hydrophilic sites and amphipathic compounds of xanthan gum, results in the production of insoluble substance. At pH 6, positive charge on LDL and negative charged xanthan gum interacts with each other to develop electrostatic force results in self-aggregation due to high percentage of hydrophobic apoproteins, which confirm by using confocal laser scanning electron microscopy shows that lipid-rich aggregates attached to the guar gum (**Navidghasemizad, et al., 2015**).
Xanthan gum having higher viscosities and influence with temperature. A helix-like structure which considered to be rigid rod formed below the transitional temperature, due to inter-molecular bonds which is responsible to become viscous solutions. The viscosity of xanthan solutions decreases with decrease in the shear rate (**Phillips & Williams, 2009**). The interactions between xanthan gum and yolk enhances during mixing and centrifugation due to external force results in viscosity reduction. Hence, after the removal of external forces solution reform gel network and become viscous. These helps to separate the cream from the aqueous phase in which major components of lipids i.e. LDL trapped by xanthan gum network due to density difference (**Navidghasemizad, et al., 2015**).

CHARACTERIZATION OF EGG YOLK

Phosphatidylcholine detection

The phosphatidylcholine (PC) i.e. 80.5% accumulated in the phospholipids which is major composition of egg yolk. These phospholipids prevent the crystallization of fatty acids with increasing the bioactivity (**Shen & Lai, 1994; Chi & Lin, 2002**). Due to the pharmaceutical importance phosphatidylethanolamine and phosphatidylcholine has gain the interest of many researcher (**Hradec & Dufek, 1997**). The major attention of industry, where egg yolk phosphatidylcholine (high purity) is utilizing as emulsifier or liposome. The importance of choline is that involves in the many biological process, and can be ingested as free base in the form of phosphatidylcholine (**Cheng et al., 1996**).
The American Oil Chemists' Society (AOCS) Official Method Ja7b-91 used for detection of phospholipids, in which silica gel column with (UV) detector employed (**Carelli et al.1997**). These utilize n-hexane/2-propanol/ acetate buffer as mobile phase. **Balazs et al. (1996)** analyze phospholipid by using improved method, which include reverse-phase solvent method with UV detection and normal phase column and also a binary gradient normal-phase method with evaporative light scattering detector (ELSD) detector. However, for the enhancement of separation efficiency and peak shape, all the above method uses solvent system as mobile phase (acetonitrile/water and hexane/2 propanol/water, with addition of methanol sometimes). But disadvantage of the system is that it effects on the efficiency of separation as well as on life span of silica gel column (**Jing et al., 2012**).
Jing et al. (2012) reported stable, silica column-friendly estimation method for egg yolk phosphatidylcholine in crude phospholipids is HPLC-ELSD, which is very sensitive and
The use of water in the mobile phase was avoided. The optimized HPLC operating conditions are used to achieve the desired results are as follows: 1.0 ml·min−1 flow rate, (250 mm×4.6 mm, 5 μm, Inertsil GLTM) silica gel column, a mobile phase as pure methanol, 30°C column temperature and (40°C, 0.35 MPa) low temperature evaporative light scattering detector (Jing et al., 2012). The recovery was in the range of 96.83%-101.58% with a relative standard deviation of 1.79% (n=6) and the linear relative coefficient curve is 0.998 under this optimal condition (**Jing et al., 2012**).

Xanthophylls characterization

Egg yolk is always been characterized with yellow color which owes to the presence of pigment; xanthophylls (originally phylloxanthins). **Brulc et al (**2013) analyzed egg yolk for the purpose of characterization of these xanthophylls with the help of isocratic HPLC method. They reported the presence of eight types of xanthophylls viz; capsanthin, canthaxanthin, lutein, zeaxanthin, ethyl-8′-apo-β-carotene-8′-oate, β-apo-8′-carotenal, β-cryptoxanthin, and citranaxanthin; indicated as additives in poultry feeding **(Brulc et al., 2013)**. The column employed for the purpose was ProntoSIL C30 column at 27°C and they observed an optimum separation of all E-isomers of these xanthophylls in less than 18 min. An acetone methanol triethylammonium acetate buffer (14:5:1) and acetone water (93:7) along with acetone methanol (1:4) were few of the suitable mobile phases for the separation. They observed that column temperature to influence the separation. They have reported the presence of up to four xanthophylls and traces of β-cryptoxanthin (zeaxanthin, canthaxanthin, lutein, and ethyl-8′-apo-β-carotene-8′-oate) in the analyzed eggs from four husbandries (**Brulc et al., 2013**).
Another study was carried out by **Jörg and Breithaupt (2006)** for the separation of eight xanthophylls used to fortify poultry feed with a high-performance liquid chromatography diode array detector (HPLC-DAD) method. Egg yolks from eggs of four types of husbandries were analyzed and they found the principal xanthophylls to be lutein and zeaxanthin. These xanthophylls ranged from the concentration of 1274 to 2478 μg/100 g and from 775 to 1288 μg/100 g, respectively (**Jörg & Breithaupt, 2006**). They also reported the levels of presence of synthetic xanthophylls to be canthaxanthin, 707 μg/100 g; β-apo-8‘-carotenoic acid ethyl ester, 639 μg/100 g; and citranaxanthin, 560 μg/100 g (**Jörg & Breithaupt, 2006**). Xanthophyll; β-apo-8‘-carotenoic acid ethyl ester was found to have highest stability in boiled eggs whereas, lutein underwent highest degradation extent (19% loss) (**Jörg & Breithaupt, 2006**).

Lipid profiling

Majority of the lipids those are present in eggs are concentrated in egg yolk. Lipid profiling study serves as a tool for primary analysis for lipid for the presence of cholesterol, triglycerides etc. **Campos et al (2016)** studied lipid profiling of eggs with respect to different diets (vegetable versus animal) and raising environment (free-range versus indoor) of hens and their impacts on egg lipid quality. They found these factors to affect the egg yolk lipid quality (**Campos et al., 2016**). They extracted total lipids from egg yolks and fractionated them into phospholipids and triacylglycerol with the help of solid-phase chromatography. HILIC-LC-MS/MS was employed for the analysis of phospholipid fractions whereas ESI-Ms was used to study triacylglycerol fraction. They reported diet practices as well as raising practices affect the lipid profiling of hen's eggs.
They reported presence of five classes of phospholipids in egg yolk viz; phosphatidylethanolamine (PE), lysophosphatidylethanolamine (LPE), phosphatidylcholine (PC), lysophosphatidylcholine (LPC) and sphingomyelin (SM) as shown in table 1.

Table 1 Lipid profile of egg yolk

Lipid fraction		Molecular species	Ions
Phospholipids	Phosphatidyl-ethanol -amine	12 (diacyl) + 1 (alkyl acyl)	[M-H]-
	Lysophosphatidylethanolamine	3	[M-H]-
	Phosphatidylcholine	22	[M+CH3COO]-
	Lysophosphatidylcholine	6	[M+CH3COO]-
	Sphingomyelin	12	[M+CH3COO]-
Triacylglycerol		10	[M+NH4] +

(Source: Campos et al. (2016)

They detected phosphatidylcholine and lysophosphatidylcholine as [M+CH3COO]- ions with the help of LC-MS spectra. They also reported presence of 22 molecular species of phosphatidylcholine with PC (16:1/18:0 and 16:0/18:1) in dominance. They reported phosphatidylcholine to be mainly comprised of n-6 fatty acids (linoleic acid). Presence of [M-H]- ions were recognized as phosphatidylethanolamine and lysophosphatidylethanolamine with the help of LC-MS spectra. They reported presence of twelve diacyl molecular species and one alkyl acyl species for phosphatidylethanolamine. LC-MS spectra also detected presence of twelve molecular species of sphingomyelin as [M+CH3COO]- ions. **Campos, et al., (2016)** further reported ten molecular species of triacyl glycerol's as [M+NH4] + ions.
Phospholipid fractions of egg yolk contained fatty acids; palmitic acid (C16:0), palmitoleic acid (C16:1), linoleic acid (C18:2), stearic acid (C18:0), oleic acid (C18:1 Δ9 cis), dihomo-γ- linoleic acid (C20:3) and arachidonic acid (C20:4 Δ6) in abundance whereas triacylglycerol fraction contained C18:1 and C18:2 w in abundance (**Campos et al., 2016**). **Özcan et al. (2019**) investigated the influence of boiling process on the quality of fatty acid composition of egg oil. They observed that myristic, palmitic, elaidic, linoleic, behenic, and erucic acid decreased in boil egg yolks in comparison with raw, whereas stearic, oleic, linolenic increased in boiled egg oil in comparison with raw egg yolk.

Color stability in egg yolk

Color of eggs is one of the vital parameters that affect consumer acceptability of eggs as well as eggs-based products. **Min et al., (2005)** have reported color of egg components to get affected by their physicochemical properties. Fat soluble carotenoids have found to be responsible for the color of egg yolk. These carotenoids include xanthophyll such as lutein, zeaxanthin and beta carotene (**Li-chan and Kim., 2008**)
De souza and Fernandez (2011) have reported an increase in b value of egg yolk when subjected to pasteurization and UV-C radiation mainly because of the carotenoid's destruction and Millard reaction.
Llave et al (2017) have stated about temperature to interfere the color properties of egg yolk. They listed main reason behind this to be thermal protein denaturation (TPD). As per their reports, according to DSC thermograms, the peaks for transition temperature were found to be at 74.14ºC and 83.85ºC for due to thermal protein denaturation. **Laca et al (2010)** has mentioned the egg yolk granules to possess an additional transitional temperature of 90.7ºC. the probable reason behind this is the presence of phosvitin which has resistive properties against heat denaturation.
Since, this thermal protein denaturation reaction proceeds progressively, **Llave et al (2018)** have explained the degree of denaturation of egg yolk proteins due to temperature to be responsible for changes in color and the extent can be properly correlated from thermal protein denaturation behavior and from the mathematical estimation of the non-denaturation ratio of egg yolk proteins.
Lipid oxidation is also responsible for alterations in organoleptic properties of food products (**Oliveira et al., 2009**). **Abreu et al (2014)** investigated inhibition of this oxidation reaction in spray dried egg yolk with the help of anacardic acid and its effect on color stability of these egg yolks. The carotenoid present in egg yolk is responsible for the color of egg yolk and contain unsaturated bonds. These bonds undergo alterations as lipid oxidation process commences (**Du and Ahn., 2000**) and as a result the yellowness (b* value) of egg yolk decreases (**Abreu et al., 2014**). As the intensity of yellow color has remarkable contribution in acceptability of the egg yolk; **Abreu et al. (2014)** tried addition of anacardic acid in egg yolk and found this addition to retain the color intensity to an elevated extent. This is mainly because anacardic acid acts as an antioxidant and reduces oxidation in dose of 150 mg/kg. **Du and Ahn, (2000)** also reported retention of yellowness in spray dried and irradiated egg yolk with the help of anacardic acid as compared with other synthetic antioxidants.

EFFECT OF DIFFERENT PROCESSING'S ON EGG YOLK

Spray drying

Spray drying is a method of producing a dry powder from a liquid or slurry by rapidly drying with a hot gas. Powdered eggs contain a
high percentage of egg yolk which indicates that they are rich in protein. The protocol for the commercial preparation of egg yolk powder is developed from reported **Rannou et al. (2015)** and shown in fig 2. The emulsifying property, viscosity, solubility and physical properties of egg yolk powder get influence by spray drying temperature (160/180°C) as well as during storage also. The n-3 enriched powders prepared by using spray drying techniques also exhibit lower color with less viscosity but less affect to functional properties as compared to egg yolk powder. These authors observe the changes in the sensory quality during storage at 30°C (**Rannou et al. 2013**), which further improvement in the qualities of egg yolk powder carried out by providing n-3 enrichment in diet to hen (**Rannou et al., 2015**).

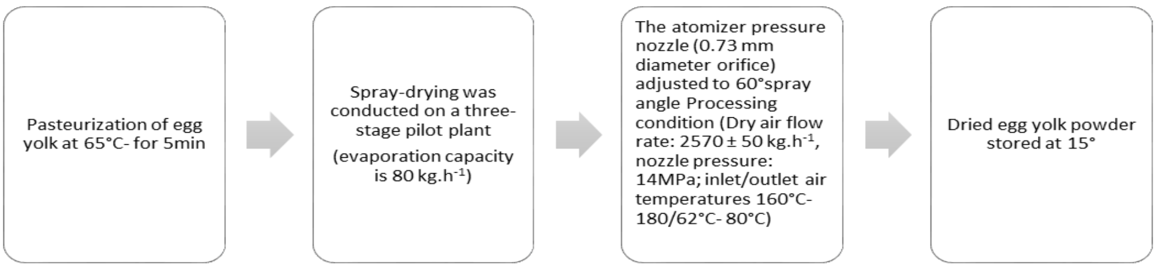

Figure 2 Processing flow diagram for preparation of egg yolk powder by using spray drying **(Rannou et al., 2015)**

Effect of freezing and thawing

After the isolation of egg yolk can be preserved by freezing at -20 ºCover 10 h. Due to freezing at -20 ºCover 10 h results in breaking in granules of yolk with the effect of protein denaturation. These freezing processes induce gel formation during storage of 10h due to the interaction of protein one which release from the granules with low density lipoproteins (LDLs) in plasma (**Au et al., 2015; Au et al., 2016**). These freezing techniques effect on the functional properties of egg yolk

like reduction in fluidity, decrease in emulsifying ability, and increase in viscosity (**Au et al., 2015**). The consequence of frozen egg gel yolk seen on quality of food where it can be use as ingredient and freezing is that main process which helps to extend the self-life of food products. Hence, **Liu et al. (2018)** investigate heat-induced gels obtained from frozen-thawed egg yolk effects on microstructure, rheological, and textural characteristics. Initially, gel like matrix form in egg yolk during the treatment of freezing and thawing which further react with protein present in yolk after the application of heat result in the formation of cross-link structures referred as heat-induced gels frozen-thawed. These studies show that heat induced gelling ability is retain after being frozen. But, as reduction in yolk/ water ratio, results in yolk gelation ability after frozen-thawed by lowering hardness and elasticity. The salt also shows the improvement in textural characteristics as increase in the salt content from 0 to 2% on heat-induced gels from frozen-thawed egg yolk, where sugar shows insignificant effect. The formation of crosslink structure between LDLs in plasma and solubilization protein from granules due to the salt which destroy the egg granules, which results in tighter cross-link structures (**Raikos et al., 2007**). **Danilenko et al. (1985)** reported that hydrophobicity increases due to salt addition which inhibit interaction between the hydrophilic molecules of protein with water to favored gels conformation. On the other side of reaction repulsive force between protein molecules enhance to create shielding effect due to addition of salts and results in the formation of aggregates to creates protein water interactions and protein -protein interactions (**Choi et al., 2000**).
The technological advances in the prevention of yolk gelation during freezing and thawing were documented by **Primacella, et al. (2018)**. The functionality of yolk in food formulations was negatively affected by gelation. Researchers used higher concentration of sugar/salt (upto 10%) to understand the effect on gelation (Liu et al., 2018), but it also limited the applications of yolk. Recent trend towards consumption of low concentration of salts and sugars, **Primacella et al. (2018)** study the effect of different hydrocolloids such as hydrolyzed carboxymethyl cellulose (HCMC), proline, hydrolyzed egg yolk and egg white results in significant reduction of hardness for 45 h of freezing at−20 °C and emerge as, novel food additives considered as gelation inhibitors. The hypothesized given by author is that ice crystal formation may contributes in gelation which led to dehydration and aggregation of lipoproteins, and use of these hydrocolloids may avoid exposure of hydrophobic site, reduce freezable water and aggregation of lipoproteins, results in prevention of gelation (**Primacella et al., 2018**).

Effect of Ohmic processing pasteurization on egg yolk

Ohmic heating is one of the novel technologies employed in food industry wherein a current is passed through the food substance which acts a resistance resulting in heat generation within the food matrix. The efficiency of this process is dependent on the conductivity of the particular food product to get processed (**Icier, 2003; Shirsat et al., 2004**). **Darvishi, et al. (2012)** studied ohmic heating process of egg yolk. They reported electrical conductivity of this egg yolk to get increased with an increase in the temperature. The possible reason behind this is an increase in the mobility of ions owing to the structural changes during the heating process. The rate oh ohmic heating was found to be 1.54ºC/sec for egg yolk. Properties of the egg yolk were found to be retained with the help of ohmic heating when compared with conventional heating process.

Effect of ultrasound on egg yolk

Ultrasound processing is one of the ways to achieve physical and chemical changes food and food ingredients which enhance the properties of food and food ingredients **(Ambadgatti et al. 2020). Geng et al., (2021)** studied the depolymerization on egg yolk due to ultrasound treatment. They stated that ultrasound treatment resulted in depolymerisation of egg yolk and the granular size was reduce to 181 nm from 289.4 nm (untreated). Further they reported that it also helps in increasing solubility of egg yolk, it is might be due to increased polarity of egg yolk after ultrasound treatment. Studied the effect of ultrasound on functional properties of egg yolk and they reported functional properties were improved after treatment. They observed that emulsification, forming and gel propertied of egg yolk were increased significantly after treatment.

Effect of high-pressure processing

Singh1 & Ramaswamy, (2013) studied effect of HPP on color and textural properties egg yolk, they reported that HPP shows significant effect. Above 600 MPa pressure egg yolk gel formation properties were improved and egg yolk able to make gel at low temperature than the required for untreated one. They also reported that the viscosity of egg yolk was increased. Further they reported that the color of egg yolk was changed from pale yellow to orange yellow. **Aguilar et al (2007**) was also reported that HPP increases the viscosity of egg yolk dispersion.

THE APPLICATION OF EGG YOLK

Salted egg

In China and other Asian countries, the salted eggs are very popular and traditional egg products in demand and base ingredient for many Chinese products like mooncakes, cuisines, egg yolk puffs and Zongzi. The salted eggs can be prepared by using pickling process in which incubation of eggs are carried out at room temperature in high concentration of salt for the period of 4 to 5 weeks. During the salting process, the egg yolk changes to hardened and solidify which results in loose, fine, fresh, gritty, tender, and oily texture after processing to high temperatures. These process results in deposition of highest concentration of salts in egg yolks which is around of 7 to 10% (**Xu et al., 2017**). **Xu et al. (2018)** developed low salinization process by using 20% salt as mass fraction in which eggs were deep in brine solution at 1:1(w/w) ratio.

Mayonnaise

Mayonnaise is O/W emulsion which made with vinegar, oil, and egg yolk and also having optional ingredient which widely use as sauces. Egg yolk is key ingredient in mayonnaise due to its good stabilizing and emulsifying properties which contributed by phospholipids and lipoproteins (**Langton et al., 1999**), but the shelf life of the product is limited due to liquid egg. These can be overcome with the application of freezing or spray-drying. **Harrison et al. (1986)** reported that these process results in reduction of solubility with increasing viscosity. **Huang et al. (2016)** used frozen yolks in mayonnaise which stored at -18°C for 0, 30, 60, 90, 120 days, results in increased values of hardness compared to fresh egg yolks. But, sensory acceptance for frozen yolk shows it is acceptable upto 60 days which might be due to the changes in secondary structure which becomes more hydrophobic (**Huang, et al., 2016**).

Egg yolk in steam bread and cake associated with baking

Egg white has been extensively used in various products since ages to improve nutritional, textural characteristics of these products owing to its functional properties as well as nutrient density. However, application of egg yolk in such products are rarely reported.
Sang et al. (2019) studied effects of egg yolk lipids in steamed bread processing. During this study, they found the polarity of these egg yolk lipids in a decreasing order with phospholipids followed by diacylglycerols, cholesterol, triacylglycerols and cholesterol eseters. Depending on this polarity, phosphotidylcholine and cholesterol increases the viscosities of starch gelatinization causing more amylose leaching (**Tang & Copeland., 2007**). They further reported the crystallinity to get decreased with the addition of egg yolk. Hence, egg yolk can be a proven natural and efficient agent for inhibition of retrogradation of starch-based products and improvise textural profile of these products.
Egg yolk as in whole or its components have a profound effect on gel formation. Egg yolk when heated produces a multidimensional network of proteins (**Powrie & Nakai., 1985**). The main proteins involved are livetin and vitellenin. Heating these proteins results in their denatured products ά-, β- and γ- livetin and vitellenin (**Le Denmat et al ., 1999**). This thus results in gel formation enforced by vitellenin. **Deleu et al.,** (2017), studied formation of protein network during cake baking. They mentioned disintegration of egg yolk granules to enhance gel formation functionality. The detailed mechanism includes egg yolk plasma and granule proteins to get bound in a covalent network bind of proteins with SS (Disulfide) bonds. Mixing batter results in granule disintegration. During the course of baking, SH/SS exchange reactions occur as a result of involvement of yolk proteins (with free SH group of livetin) and granules. As baking progresses, ovalbumin also gets involved (**Deleu et al., 2017**). They further mentioned, there is no role of phosvitin in the protein network via disulfide bridge formation because it lacks both intermolecular disulfide bonds and free sulfhydryl groups (**Deleu et al., 2017**).

Effect of phospholipids extracted from egg yolk on meat

Lipids and compound derived thereof plays a major role in the development of particular meaty flavor in various meat-based products (**Jayasena et al., 2013**). In the same manner the phospholipids compounds present in the egg yolk also can be a possible source for the fabrication of such flavors. **Chen et al., (2019)** extracted these lipids from the egg yolk samples and identified a number of volatile components present in the headspace of their storage volume alike chicken as shown in table 2. They categorized these volatile components based on their compound of origin into 7 groups.

Table 2 Volatile components from extracted phospholipids from egg yolk on chicken

ω-3 derivatives	ω-6 derivatives	ω-9 derivatives	Ketones	Maillard reaction products	Sulfur compounds	Miscellaneous
2-Propenal Butanal 2-Ethylfuran 1-Penten-3-one 1-Penten-3-ol 1-Penten-3-ol 2-Hexenal (E) 2-(2-Pentenyl) furan (E) 2-Penten-1-ol (Z) 2,4-Heptadienal (E,Z) 2,4-Heptadienal (E,E) 3,5-Octadien-2-one (E,E) 1-Pentanol	Pentanal Hexanal Heptanal 2-Pentylfuran 2-Heptenal (E) 1-Octen-3-ol 1-Octen-3-one 2-Octenal (E) 3-Octen-2-one 3-Nonen-2-one 2-Nonenal (E) 2-Octen-1-ol (E) 2-Decenal (E) 2,4-Nonadienal (E,E) 2,4-Decadienal (E,Z) 2,4-Decadienal (E,E)	1-Decene Octanal Nonanal Decanal 1-Octanol 1-Nonanol 1-Decanol 2-Undecenal	2-Pentanone 3-Hexanone 2-Heptanone 6-Methyl-2-heptanone 3-Octanone 2-Octanone 2,3-Octanedione 3-Ethylcyclopentanone 2-Nonanone 2-Decanone 3,5-Heptadien-2-one 2-Undecanone	2-Methylbutanal 3-Methylbutanal 2,3-Butanedione 2,3-Pentanedione 2-Furfural Tetramethylpyrazine Benzeneacetaldehyde	Hydrogen sulfide Methanethiol Carbon disulfide Dimethyl sulfide Dimethyl disulfide Dimethyl trisulfide Methional	Nonane 1-Hexanol 1-Tetradecene Undecanal 6-Methyl-3,5-heptadiene -2-one Dodecanal

*Source (List is prepared from Chen et al. 2019)

Nanogels

A synthetic polymers or biopolymers are used in the preparation of nanogel in which nanoparticle composed of a hydrogel due to crosslinking of hydrophilic polymer network by using physical or chemical method. An egg yolk low-density lipoprotein (LDL)/polysaccharide nanogels was invented by **Zhou, et al. (2018)** for oral delivery systems. The nanogel stability influence by aggregation in gastrointestinal tract. These challenges overcome with chemical crosslinking between 1-ethyl-3-(3-dimethylaminopropyl) and carbodiimide/N-hydroxysuccinimide (EDC/NHS). This crosslinking method reduced surface charge without influencing morphology, polydispersity index (PDI), and particle size compared to uncross linked gel which further dried by using spray drying technology results into poor surface structure due to agglomeration (**Zhou, et al., 2018**). The LDL-based nanogels stability in digestive conditions due to formation of new peptide bond as well as improvement in the encapsulation efficiency which provide strength to curcumin which incorporated into the nonpolar region. The strong non-polar region is developed due to the cholesterol ester molecules and triacylglycerol present in LDL **(Yu & Huang, 2010)**. The encapsulation efficiency of curcumin increases with the application of chemical crosslinking, which might be reshuffling of lipids and LDL apoprotein carried out during nanogels fabrication due to hydrophobic interactions provide strength to non-polar core **(Ying et al., 2011)**.

Zhou, et al., (2016) also develops the egg yolk LDL complex nanogel by using different polysaccharides such as alginate, cellulose (CMC), pectin, carrageenan, and gum arabic to delivered lipophilic nutrients efficiently (**Zhou, et al., 2016**), and also, he obtains ultrafine nanogel powder by exploiting nano spray drying as novel tool.

CONCLUSION

This review provide insight on nutritional bioactive components present in proteins and lipids. Egg yolk is source of proteins like phosvitins and lipovitellins, and lipids composed with phosphatidylcholine. Egg yolk proteins posse's good gelation and water holding properties. The mechanism behind the exact nature of interaction of LDL and xanthan gum is lacking and need to be provide insight on three phase separations based on the application of anionic polysaccharides for further potential application in food industry. There is need to be focused on more hydrocolloids apart from sugar/ salt to avoid gelation and more focus need to be understand the mechanism behind gelation of yolk induced due to processing like freezing-thawing. The functional property of the egg yolk is influenced with different processing. The egg yolk can be used in bakery product which are high in starch like steam bread to produce soft firm quality and also build up protein network during baking (e.g. pound cake). The novelty of phospholipids in chicken as odorant has been reviewed, but it is need to be focused on other category of foods like cereals and legumes which is not yet explored. Still there is need to be developed technology for the preservation of egg yolk apart from freezing and also need to be increased processing egg yolk with different food category like cereals, beverages. The nanogel is emerges as novel technology to deliver lipophilic nutrients and stabilized the LDL-based nanogels.

Conflict of Interest: The authors confirm that they have no conflicts of interest with respect to the work described in this manuscript

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