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Exploring the Potential of Omega-3 Enriched Egg Industry in Indonesia: Production, Consumer Demand, and Competitiveness

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ABSTRACT

People are worried about the health impacts of the cholesterol contained in egg. Various studies show that adding omega-3 to laying feed or drinking water will produce omega-3 eggs that are low in cholesterol. This research aims to determine the potential for developing the omega-3 egg industry in Indonesia. Secondary data (from BPS and related literature), and primary data (from interviewed with sample farmers) were analyzed using revenue cost (R/C) ratio, willingness to Pay (WTP) and descriptives analysis. The findings showed that farmer produced omega-3 eggs from small scale (100 birds) to large scale (50,000 birds). Farmer introduce omega-3 through feed in the form of (1) a mixture of salmon oil with vegetable oil, (2) maggots (Hermetia illucens), and (3) processed fish waste. Each provided R/C ratios of 1.10, 1.34, and 1.52. The competitiveness of the omega-3 egg industry in Indonesia is quite strong, supported by (1) abundant sources of omega-3 supplement feed, (2) increasing demand for omega-3 eggs, (3) supported by feed and the pullet industry (4) low competition of omega-3 eggs producer, and (5) support for stunting reduction programs through protein consumption.

Keywords: competitiveness, consumer demand, industry, omega-3 egg, production

ABSTRAK

Masyarakat khawatir dengan dampak kesehatan dari kolesterol yang terkandung di dalamnya. Berbagai penelitian menunjukkan bahwa penambahan omega-3 pada pakan ayam petelur atau pada air minum akan menghasilkan telur omega-3 yang dapat menurunkan kolesterol. Penelitian ini bertujuan untuk mengetahui potensi pengembangan industri telur omega-3 di Indonesia, menggunakan data sekunder dari BPS serta literatur terkait, dan data primer hasil wawancara dengan peternak sampel. Analisis data menggunakan statistik deskriptif, willingness to pay (WTP) dan rasio revenue cost (R/C). Hasil penelitian menunjukkan bahwa telur Omega-3 diproduksi dalam skala kecil (100 ekor) hingga skala besar (50.000 ekor). Sumber omega-3 bervariasi, yaitu (1) campuran minyak ikan salmon dan minyak nabati, (2) maggot (Hermetia illucens), dan (3) olahan limbah ikan (telur omega-3 IPB). Masing-masing sumber omega-3 memberikan rasio R/C sebesar 1.10, 1.34, dan 1.52. Disimpulkan bahwa daya saing industri telur omega-3 di Indonesia cukup kuat, dengan syarat: (1) masukan pakan suplemen omega-3 melimpah, (2) permintaan telur omega-3 dalam negeri terus meningkat, (3) didukung oleh industri pakan dan ayam dara (4) tingkat persaingan industri telur omega-3 masih rendah, (5) didukung oleh program pemerintah untuk menurunkan stunting melalui konsumsi protein.

Kata kunci: daya saing, industri, rasio revenue-cost, telur omega-3

INTRODUCTION

Indonesia still imports (in 000 USD) 55,000 milk powder and 829,885.3 beef meat (Central Bureau of Statistics 2022), to meet the consumption of animal protein for 273 million people. The nutritional adequacy rate according to the Minister of Health of the Republic of Indonesia (2019) for protein consumption is 65 grams and 60 grams per day for adult men and women, respectively. During the covid-19 pandemic in 2020, consumption of animal protein increased by 1.14% compared to 2019 (Central Bureau of Statistics 2021). According to Sumarmi (2020), to increase body immunity, protein consumption needs to be increased to 75-100 grams per day. Proteins play a role in the formation of immunoglobulins (Ig), where the specific immunoglobulins that play a role against the SARS-Cov 2 virus are IgM and IgG (Sumarni 2020).

In order to reduce imports, the increased in demand for animal protein can be met from eggs that are easy to produce domestically. Intake of 75-100 grams of protein per day during a pandemic can be obtained from consuming 2 eggs, 5-6 pieces of fried tempeh, and one piece of chicken breast or one medium-sized fish (Sumarmi 2020). Eggs contain vitamins, minerals, high-quality protein, essential fatty acids, phospholipids, sphingomyelin, lutein, zeaxanthin, as well as various bioactive components, antioxidants and choline (Sanlier 2021). Egg bioactive components as pro- and anti-inflammatory play a role in disease pathophysiology (Andersen 2015), showing antimicrobial, immunomodulatory, antioxidant, anticancer, or antihypertensive effects.

However, people are worried about the danger of cholesterol contained in eggs. Whole eggs contain around 186 to 230 mg of cholesterol, which is feared to cause cardiovascular risk (CVD) and hypertension (Sanlier 2021). The risk of hypertension increases in people who consume eggs every day. Egg consumption also increases blood glucose concentration (Guo *et al*. 2018).

Public concern about the cholesterol content in eggs can be overcome by producing omega-3 enriched eggs. Hens whose feed is supplemented with an omega-3 source, produce eggs that contain higher in omega-3 (Sumiati *et al.* 2022; Kartika *et al*. 2017; Ehr e*t al.* 2017; Imran *et al*. 2015; Rahayu 2013), contain vitamins, several minerals, such as selenium, proteins and other different important nutrients (Gjorgovska and Filev 2011; Leeson and Caston 2003; Park and Stoel 2005; Park *et al*. 2018; Stadelman 1999).

Omega-3 enriched eggs are considered a suitable functional food (Gjorgovska and Filev 2011), since they have a potentially beneficial impact on health when consumed regularly and at effective levels as part of a varied diet (American Dietetic Association 2009). Consuming omega-3 enriched eggs can reduce the risk of coronary heart disease, cognitive decline, cancer, and neurodegenerative diseases (Shahidi and Ambigaipalan 2018; Lange *et al*. 2019, Candela *et al.* 2011).

According to Polaris (2022), the global omega-3 market in 2021 valued at USD 2.19 billion and is expected to grow at a CAGR (compounded annual growth rate) of 8.0% during 2022-2030 (Polaris 2022). The growing incidents of cardiovascular diseases, altering dietary habits, and growing significance of immunity development post-covid-19 pandemic are the driving force for omega-3 market. Panse & Phalke (2016) cited that omega-3 enriched eggs are the second demanded omega-3 fortified food products. This encourages the industry development of the omega-3 enriched eggs in developed country such as Canada (Chase *et al.* 2007), United State (Bakhtavoryan and Lopez 2020), and Italy (Palmieri *et al*. 2022). This study aims to explore the potential of the omega-3 enriched egg industry in Bogor, Indonesia, from the side of producers, consumers as well as business competitiveness.

MATERIAL AND METHODS

Data Collection

This research used secondary data and primary data. Secondary data were collected from the literature available online, namely from the Central Bureau of Statistics, online journals and research institute reports. The primary data consisted of production profit potential, consumer potential as well as business competitiveness of omega-3 eriched eggs industry. Primary data was collected through a structured questionnaire.

Production profit potential data were collected from 3 farmers in Bogor. Purposive sampling was used to select individual farms from Bogor Regency, who used different sources of omega-3 for layer feed supplements. Potential consumer data were obtained from 41 respondents who lived around IPB University, Bogor, Indonesia. Stratified and random sampling was used to select respondents who represent student respondents, posyandu officials (posyandu = integrated health and family planning service post), as well as lecturers and staff at IPB university. Communities around the campus were selected as research targets with the consideration that they were potential consumers, since they had relatively good knowledge about the benefits of omega-3 enriched eggs.

Data of business competitiveness of omega-3 enriched egg industry were obtained from 3 academic respondents, experts in the field of omega-3 egg production, functional food experts and marketing experts. In-depth interviews guided by key questions were used to explore data from experts.

Data Analysis

Producer Potential

The potential from the producer side is proxied from the profits of the omega-3 enriched egg business using revenue (R) cost (C) analysis (R/C analysis) (Suratiyah, 2015), using the formula:

$$\frac{R}{C} = \frac{R}{\sum_1^2 c_i}$$

r_i = revenue from eggs production (IDR)
c_i = variable cost and fix cost (IDR)

The omega-3 enriched egg business is profitable if the R/C ratio is greater than 1.

Consumers Potential

Potential consumers were analyzed using willingness to pay (WTP) for omega-3 enriched eggs. The determinant variable of WTP was analyzed using the following linear equation (Greene 2003):

$$WTP = \propto + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 + \beta_5 X5 + \epsilon$$

Where:

WTP = willingness to pay (IDR/egg)
$\propto$ = constant variable
b_i =coeffisient of independent variable (individual characteristic)
X1 = age (year)
X2 = sex (male =1; female =0)
X3 = education (senior high school =1; undergraduate student =2; fresh graduate =3; graduate; post graduate S2/S3= 4)
X4 = household spending for omega-3 egg (IDR/month)
X5 = total household spending (IDR/month)
ϵ = residue

Business competitiveness

Business competitiveness of omega-3 enriched eggs industry were analyzed using the model Porter Diamond (Porter 1990).

RESULTS AND DISCUSSION

Farm Profile and R/C Ratio

All farmer respondents were male individuals who had obtained bachelor's degrees. Omega-3 for feed supplements have different sources, namely from salmon and vegetable oil mix, maggot flour and fish processing industry waste (Table 1). Fish oil was used by 2 of the 3 respondents studied. Fish oil contains high levels of unsaturated fatty acids, especially omega-3, docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA) (Fraeye *et al*. 2013). Salmon, mackerel, and sardines are oily fish (Reinagel 2019). Soesanto's research (2013) showed a decrease in fat content, total cholesterol and NaCl in chicken eggs fed with fish oil supplements. Supported by Mansoub & Bahrami (2011), fish oil supplements can reduce the content of omega-6 (AA, arachidonic acid) in eggs. A high ratio of omega-6:omega-3 is harmful to health because it increases the production of pro-inflammatory cytokines (Ibrahim *et al.* 2018) and increases the risk of chronic diseases, such as heart and blood vessel disease, type II diabetes mellitus, and joint inflammation (Diana 2012).

Maggot can be used as an alternative feed ingredient because it contains 41-42% crude protein, 31-35% ether extract, 14-15% ash, 4.18-5.10% calcium, and 0.60-0.63% phosphorus (Ambari 2020). Substitution of maggot flour in commercial feed was significantly different between treatments for increasing the content of Omega-3 Eicosapentanoic Acid (EPA) in tilapia (*Oreochromis niloticus*) meat (Putri 2017). Research on maggot as layer feed had been carried out by several researchers including Sumiati *et al.* (2022b). The results showed that the cholesterol content in eggs decreased from 181.25 to 175.00 (mg/dl) when using maggot which increased from 10% to 15% (Sumiati *et al.* 2022b).

Other study (Rido 2021) used maggot which was bred with a growth medium of 8% lemuru fish oil, as a feed mixture to produce omega-3 enriched quail eggs. Using 6% maggot can increase egg production and reduce feed conversion, because maggot contains 55% protein, 35% fat, omega-3, vitamins, minerals, fiber and essential amino acids such as histidine, glutamic acid, aspartic acid, methionine and cystine.

In Indonesia, there is no obligation for farmer to certify omega-3 enriched eggs. Certification is still voluntary, generally by relatively large farms. The buyer believes in the seller's figure, even without showing a certificate. Business scale is from 100 to 1,000 layers, using different strain layers (Lohmann, Arab and Isabrown). Hen day is between 87 to 90 with zero mortality. Based on the source of omega-3 used for supplements, the highest R/C was achieved by farmers who used sources of omega-3 from fish processing industrial waste, i.e 1.52. The smallest R/C was obtained by farmers using maggot as an omega 3 source.

The highest production costs are using omega-3 supplements from a mixture of palm oil with fish oil, and the lowest costs are from fish processing industrial waste. The selling price depends on the place where the eggs are sold. The highest price is paid by household consumers. Each source of omega-3 provides a revenue cost ratio (R/C) of 1.10, 1.34, 1.52.

R/C achievement is also determined by hen day. Hen day layer between 88% to 90%. This value is higher than

Table 1. Omega-3 egg business profile

Parameter	Unit	Farm-1	Farm-2	Farm-3
Omega-3 source		Salmon & vegetable oil mix	Maggot flour	Fish processing industry waste
Layer strain		Lohmann	Arab	Isabrown
Business Scale	birds	1,000	100	250
Hen day	%	90	88	90
Production cost	IDR/10 eggs	24,545	20,105	19,763
Sales to		pharmacy, supermarket	herbalist, household	household
Selling price	IDR/10 eggs	26,000-27,000	27,000-30,000	32,000
Revenue/Cost (R/C)		1.10	1.34	1.52
Profit ranking		3	2	1

hen day layer with conventional feed, which is between 69.91% to 81.54% (Rahayu and Widjastuti, 2018), but lower than the production of the ISA Brown strain aged 24-28 weeks at CV Bisco Farm, South Lampung Regency i.e. 92.77% (Sulaiman *et al.* 2022). Egg production depends on the age of the layer. Peak production in Bisco Farm at the age of 26 weeks where hen days can reach 94% (Sulaiman *et al.* 2022).

The selling price also determines the business profit of omega-3 enriched eggs. Of the four sales locations, namely pharmacy, supermarket, herbalist and household, the highest price was paid by household consumers, namely IDR 3,200/egg (Table 1), and the lowest price was paid by supermarkets (IDR 2,600/eggs). However, the selling price of omega-3 enriched eggs to all buyers is still higher than the price of conventional eggs at the time of the study, i.e. IDR 1,500/egg (IDR 27,000/kg).

Consumer Profile and Willingness to Pay

The respondent's profile as a prospective customer is dominated by women, at the age between 20-25 years, as undergraduate student, has an income less than IDR 3,000,000 per month. Monthly spending on eggs less than IDR 50,000 per month (Table 2).

Table 2. Consumer of omega-3 egg profile

Profile	Category	(%)
Sex	Woman	85.36
	Man	14.64
Age (year)	20-25	51.22
	26-40	29.27
	>40	19.51
Education	Senior high school	24.39
	Undergraduate student	51.22
	Fresh graduate	19.51
	Post graduate	4.88
Income (IDR million/ month)	<3	48.78
	3-May	41.46
	>5	9.76
Spending for eggs (IDR000/month)	<50	41.46
	50-100	39.03
	>100	19.51

Table 3. Willingness to pay for omega-3 egg

WTP (IDR)	Number	Cumulative	Total (IDR)
2,000	12	12	24,000
2,200	2	14	4,400
2,500	10	24	25,000
2,600	2	26	5,200
2,700	1	27	2,700
2,800	1	28	2,800
2,900	1	29	2,900
3,000	12	41	36,000
Average			2,512

The potential for developing the omega-3 enriched eggs industry from potential consumers is analyzed from willingness to pay (WTP), especially consumers who do not yet need functional food. The average value of the respondent's WTP valued was IDR 2,512 per egg (Table 3), lower than the minimum price received by the 3 sample farmers, which was IDR 2,600. However, when viewed from the regression equation, the higher the level of education the higher the WTP value for omega-3 enriched eggs (Table 4), the WTP of men is higher than that of women and the higher WTP increased among consumers reporting a higher household spending.

Table 4. Determinant of willingness to pay for omega-3 egg

Predictor	Coefficient	P
Constant	1,929.30***	0.000
Age	-0.023	0.997
Sex	279.70*	0.173
Education	133.29**	0.011
Eggs spending	-0.10	0.876
Household spending	62.43*	0.172

R-Sq = 32.9%

***: significant at 1%; **: significant at 5%; *: significant at 20%

The variables affecting WTP are in line with the results of a study on WTP omega-3 enriched eggs by consumers in Italy (Palmieri *et al*. 2022), except for the sex variable, where females were more willing to pay a premium price for functional eggs than male consumers. Based on the variables affecting WTP, market development is directed at the educated and high-income household segments, especially men.

At the 5% level of significance, only education variable has positif effect on WTP. Whereas sex and household spending have an effect on the significance of 20% (Table 4). Variable of monthly spending for eggs and age have no effect on the WTP.

Competitiveness of the Omega-3 Egg Industry in Indonesia

From a competitive point of view, the development potential of the omega-3 enriched eggs industry is mapped in the Porter Diamond model (Figure 1).

There are 6 determining aspects of competitiveness (Porter 1990), namely: (1) factor conditions, (2) demand conditions, (3) firm strategy, structure and rivalry, (4) related and supporting industries, (5) chance, and (6) government policy.

1. Factor condition

a. Plentiful of omega-3 sources.
b. Indonesian sustainable production of fisheries 113.5 million tons/year,
c. Fish production 24.50 million tons, 2nd largest after China since 2009, where 35% is waste (Dahuri 2020)
d. The climate is suitable for producing maggot

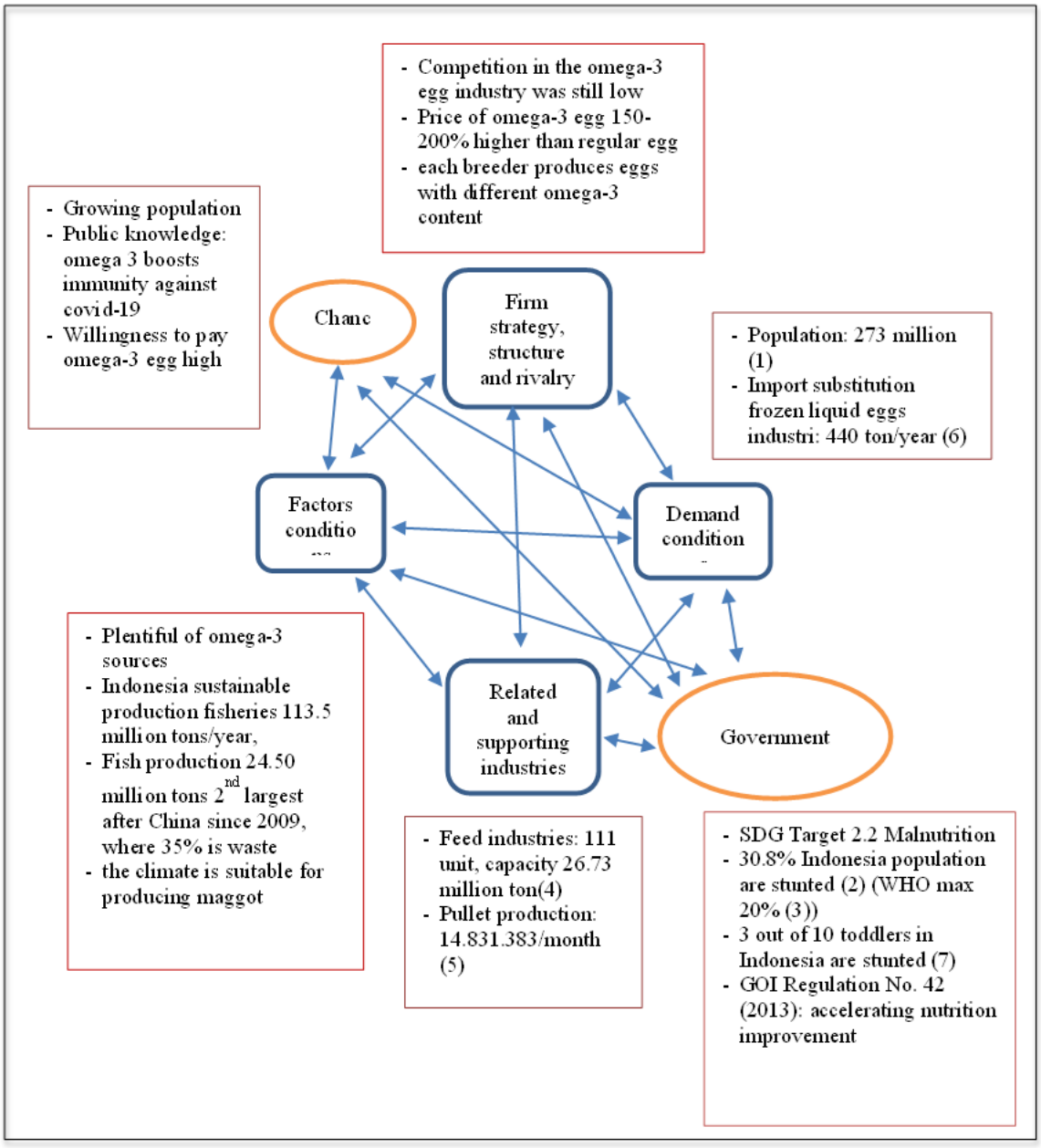

Figure 1. Porter diamond model of enriched egg industry in Indonesia

2. Demand condition.
   a. Population: 273 million
   b. Import substitution frozen liquid eggs industry: 440 ton/year

3. Firm strategy, structure and rivalry
   a. Competition in the omega-3 egg industry was still low
   b. Price of omega-3 eggs 150-200% higher than regular egg
   c. Each breeder produces eggs with different omega-3 content

4. Related and supporting industries
   a. Feed industries: 111 units, capacity 26.73 million ton
   b. Pullet production: 14.831.383/month

5. Chance
   a. Growing population
   b. Public knowledge: omega 3 boosts immunity against covid-19
   c. Willingness to pay omega-3 egg high

6. Goverment policy
   a. SDG Target 2.2 Malnutrition
   b. 30.8% Indonesian population are stunted (WHO max 20% (3))
   c. 3 out of 10 toddlers in Indonesia are stunted
   d. GOI Regulation No. 42 (2013): accelerating nutrition improvement. According to the Indonesian Ministry of Health, the Nutrition Adequacy Rate (RDA) is 62-66 grams for men and 56-59 grams for women per day. The protein requirement is equivalent to 10 eggs.

Consumers believe that functional food with added benefits are the key to be a healthy lifestyle. This interest is making a positive impact on the demand for omega-3 eggs. Key players operating in the business of omega-3 eggs in Indonesia includes Fiesta, Lourba Farm Jogyakarta, SiBakul Jogyakarta, BBPP Batu, Super Protein, etc.

CONCLUSION

It is concluded that the omega 3 egg industry in Indonesia is very profitable with an R/C ratio of more than one. The highest profits are for farmers who use processed fish waste as an omega-3 supplement in feed. The competitiveness of the omega-3 egg industry is quite strong, with the conditions: (1) omega-3 supplement feed inputs are plentiful, (2) local demand for omega-3 eggs continues to increase, (3) supported by the feed and pullet industry (4) the level of competition in the omega-3 egg industry was low, (5) supported by government programs to reduce stunting through protein consumption. Dissemination through campaigns can increase public knowledge of the importance of consuming omega-3 enriched eggs. It is very important for the omega-3 enriched egg industry to consider product safety and quality, guaranteed and consistent product quality. This information must be included on the packaging.

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REFERENCES

Ambari, M. 2020. Maggot, Serangga Pengurai Sampah untuk Pakan Ikan. Retrieved from Mongabay: https://www. mongabay. co. id/2020/0. 1(2):1.

American Dietetic Association. 2009. Position of the American Dietetic Association: Functional foods." Journal of the American Dietetic Association. 109:735-746.

Andersen, C. 2015. Bioactive egg components and inflammation. Nutrients. 7(9):7889-7913.

Bakhtavoryan, R. & J. A. Lopez, Jose. 2020. An Empirical Analysis of Factors Influencing Households' Demand for Omega-3 Enriched Eggs in the United States (September 1, 2021). Journal of Agribusiness. 38(2):161-179.

Candela, C. G., L. M. B. López, & V. L. Kohen. 2011. Importance of a balanced omega 6/omega 3 ratio for the maintenance of health: nutritional recommendations. Nutr. Hosp. 26:323-329.

Central Bureau of Statistics. 2022. Livestock in Figure. Jakarta: Central Bureau of Statistics.

Central Bureau of Statistics. 2021. Consumption of Calorie and Protein of Indonesia and Province September 2021. Jakarta: Central Bureau of Statistics.

Chase, D., T. Nilsson, J.P. Emunu, D. McCann-Hiltz, & Y. Peng. 2007. Canadian Consumer Attitudes and Purchasing Behaviour of Omega-3 Products. Consumer and Market Demand Agricultural Policy Research Network. Research Project Number CMD-07-04. https://www.researchgate.net/publication/23516256_Canadian_Consumer_Attitudes_and_Purchasing_Behaviour_of_Omega-3_Products [Accessed Nov 12 2022].

Dahuri, R. 2020. Strategy for Utilizing Fishery Waste to Increase Competitiveness, Quality Economic Growth and Sustainable People's Welfare. Presented at: Webinar "Gaining Rupiah Through the Use of Shellfish and Fish Skin" PDSPKP KKP 18 Agustus 2020. https://www.doi.org/10.31989/ffhd.v11i8.817

Ehr, I. J., M. E. Persia, & E. A. Bobeck. 2017. Comparative omega-3 fatty acid enrichment of egg yolks from first-cycle laying hens fed flaxseed oil or ground flaxseed. Poult Sci. 2017 Jun. 96(6):1791-1799.

Fraeye, I., C. Bruneel, C. Lemahieu, J. Buyse, K. Muylaert, & I. Foubert. 2013. Dietary enrichment of eggs with omega-3 fatty acids: A review. Food Research International July 2013.Gjorgovska, N.; Filev, K. Multi-enriched eggs with omega 3 fatty acids, vitamin E and selenium. Arch. Zootech. 2011. 14:28-35.

Greene, W. H. 2003. Econometric analysis. Pearson Education India.

Guo, J., D. A. Hobbs, J. R. Cockcroft, P. C. Elwood, J. F. Pickering, J. A. Lovegrove, & D. I. Givens. 2018. Association between egg consumption and cardiovascular disease events, diabetes and all-cause mortality. Eur J Nutr. 57(8):2943-2952.

Ibrahim, D., R. El-Sayed, S. I. Khater, E. N. Said, & S. A. M. El-Mandrawy. 2018. Changing dietary n-6: n-3 ratio using different oil sources affects performance, behavior, cytokines mRNA expression and meat fatty acid profile of broiler chickens. Anim. Nutr. 4:44-51.

Imran, M., F. M. Anjum, M. Nadeem, N. Ahmad, M. K. Khan, & Z. Mushtaq. 2015. "Production of bio-omega-3 eggs through the supplementation of extruded flaxseed meal in hen diet". Lipids in Health and Disease. 14:1-9.

Indonesian Ministry of Health. Minister of Health Regulation No. 28 of 2019 concerning Recommended Nutritional Adequacy Rates for Indonesian People. Indonesia Ministry of Health, Jakarta.

Kartikasari, L. R., Geier, M. S., Hughes, R. J., Bastian, S. E. P. & Gibson, R. A. 2020. Omega-3 fatty acid levels and sensory quality of eggs following consumption of alpha-linolenic acid enriched diets. Food Research. 5(Suppl. 2):57-64.

Lange, K. W., Y. Nakamura, A. M. Gosslau, & S. Li. 2019. Are there serious adverse effects of omega-3 polyunsaturated fatty acid supplements?. J. Food. Bioact. 7:1-6.

Leeson, S. & L. J. Caston. 2003. Vitamin enrichment of eggs. J. Appl. Poult. Res. 12:24-26.

Mansoub, N. H., & Y. Bahrami. 2011. Influence of dietary fish oil supplementation on humoral immune response and some selected biochemical parameters of broiler chickens. Journal of Agrobiology. 28(1):67-80.

Palmieri, N., W. Stefanoni, F. Latterini, & L. Pari. 2022. Factors Influencing Italian Consumers' Willingness to Pay for Eggs Enriched with Omega-3-Fatty Acids. Foods. 11:545-555.

Panse, L. M. & S. D. Phalke. 2016. Fortification of Food with Omega-3 Fatty Acids. Springer link. 2357:89-100.

Park, J., & L. Stoel. 2005. Effect of brand familiarity, experience and information on online apparel purchase. Int. J. Retail. Distrib. Manag. 33:148-160.

Park, S., J. Jung, S. W. Choi, & H. J. Lee. 2018. Association between egg consumption and metabolic disease. Korean Journal for Food Science of Animal Resources. 38(2):209-223.

Polaris Market Research. 2022. Omega 3 Market Share, Size, Trends, Industry Analysis Report, By Application (Pharmaceuticals, Dietary Supplements, Animal Feed, Food & Beverages, Others); By Source (Plant-based, Marine Based); By Type; By Region; Segment Forecast, 2022 – 2030. https://www.polarismarketresearch.com/industry-analysis/omega-3-market [accessed Nov 12 2022].

Porter, M. E. 1990. The Competitive Advantage of Nations. Harvard Business Review.

Putri, A. A. C. 2017. Pengaruh Subtitusi Tepung Maggot (Hermetia illucens) pada Pakan Komersial Terhadap Kandungan Omega-3 dan Omega-6 Daging Ikan Nila (Oreochromis niloticus). Thesis, Universitas Airlangga.

Rahayu, N., & T. Widjastuti. 2018. Egg Weight and Hen Day Production (HDP) Layer Commercial at High and Low Altitude. IOP Conf. Series: Journal of Physics: Conf. Series. 1179(2019):012179.

Reinagel, M. 2019. Are Omega-3 Eggs as Good as Eating Fish? Scientific American. https://www.scientificamerican.com/article/are-omega-3-eggs-as-good-as-eating-fish/

Rido, M. 2021. Produksi Tepung Maggot Black Soldier Fly (*Hermetia Illucens*) Tinggi Protein dan Kaya Asam Lemak Omega-3 serta Optimasi Pemberiannya dalam Ransum terhadap Performa Produksi Puyuh. Thesis. Padang: Universitas Andalas.

Sanlier, N. 2021. Egg consumption and health effects: A narrative review. Journal of Food Science. September 21st. Institute of Food Technologists. https://doi.org/10.1111/1750-3841.15892 [accessed Nov 12 2022].

Shahidi, F. & P. Ambigaipalan. 2018. Omega-3 polyunsaturated fatty acids and their health benefits. Annu. Rev. Food. Sci. Technol. 9:345-381.

Soesanto, I. R. H. 2013. Innovation in omega-3 protein supplements made from environmentally friendly raw materials for the production of DHA-rich eggs and business prospects. National Conference and Technopreneurship. Bogor: Institut Pertanian Bogor.

Stadelman, W. J. 1999. The incredibly functional egg. Poult. Sci. 78:807-811.

Sulaiman, D., N. Irwani, & K. M. Maghfiroh. 2022. Production Activities of Isa Brown Strain Chicken at the Age 24-28 Weeks. Peternakan Terapan. 1:26-31.

Sumarmi. 2020. Harmonity of Nutrients to Improve Immunity Against Covid-19: A Mini Review. Amerta Nutr. 250-256.

Sumiati, A., Darmawan, & W. Hermana. 2022a. Performance, Carcass Traits, and Meat Composition of Broiler Chickens Fed Diet Containing Fish Oil and Vitamin E. Trop. Anim. Sci. J. 45(2):121-246.

Sumiati, D. K. Purnamasari, Erwan, Syamsuhaidi, & K. G. Wiryawan. 2022b. The Use of Black Soldier Flyer (*Hermetia illucens*) Larvaein Feed of Laying Hens. Sains Teknologi & Lingkungan. 8(1):25-35.

Suratiyah, K. Agricultural Science. Self-Help Spreader. Jakarta. 2015.