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Omega-3 content and sensory evaluation of scrambled eggs from two strains of laying hens fed diets enriched with alpha-linolenic acid

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ABSTRACT

The objective of the study was to assess the accumulation of omega-3 (n-3) fats and the sensory quality of scrambled eggs from two strains of laying hens (brown and white) given omega-3 enriched diets. The design of this research was a completely randomized block design, with a 3 × 2 factorial. A total of 24 Hy-Line brown and 24 Hy-Line white were fed three experimental diets. The alpha-linolenic acid (18:3n3, ALA) levels of the dietary treatments were either low (0.3%), moderate (3.0%), or high (6.0%) with the linoleic acid (18:2n6, LA) level kept constant at approximately 4%en. The results showed that dietary supplementation of ALA enhanced n-3 fats and had no impact ($P>0.05$) on sensory properties including oily odour, butter aroma, sulphur aroma, taste, flavour, or off-flavour of scrambled eggs. Diets high in ALA resulted in Scrambled eggs with less intense egg aroma compared to those given diets with low or moderate ALA. Eggs of brown hens had a significantly stronger egg aroma, butter flavour, and sulphur flavour ($P<0.05$) compared to white eggs. In conclusion, the dietary inclusion of 3.0% ALA was discovered to be optimum with respect to the accumulation of n-3 fats and the sensory properties of the eggs.

Keywords: Laying hen strain, Omega-3 fat, Scrambled eggs, Sensory assessment

INTRODUCTION

Recently, many functional food products have been developed, including egg products rich in omega-3 fats (n-3 fats) which is well documented to have many beneficial health effects for human. Therefore, health authorities suggest consuming n-3 fats, especially eicosapentaenoic acid/EPA and docosahexaenoic acid/DHA (Thompson *et al*., 2019; Rao *et al*., 2020). One of the efforts to increase the concentration of n-3 fatty acids in the diet is by consuming eggs containing high levels of n-3 fatty acids. Eggs rich in omega-3 fatty acids can be produced by adding

diets with ingredients high in omega-3 long chain polyunsaturated fatty acids (n-3 LCPUFA), for example marine sources (fish meal or fish oil). As reported by Brelaz *et al*. (2019), this method is considered effective because EPA and DHA are more rapidly incorporated into plasma and lipid membranes, and this results in a faster functional effect compared to alpha-linolenic acid (ALA). The enrichment of EPA and DHA in eggs is more readily achieved by direct feeding of these n-3 LCPUFA versus ALA (Neijat *et al*., 2017). Numerous studies have shown that adding fish meal or fish oil into the diet of hens can enhance the production of n-3 LCPUFA, particularly EPA and DHA (Kralik *et al*., 2021). However, other researchers reported that the inclusion of fish products in layer hen diet resulted in a decline in the sensory properties of the final product, as reported by fishy odour (Brelaz *et al*., 2019) and fishy off-flavour (Chekani-Azar *et al*, 2008). To preserve the organoleptic qualities of eggs, fish oil could be incorporated into laying hen diets up to a level of 1.5% (Yalcin, 2017).

The dietary supplementation of n-3 source ingredients from plants in hen diet an alternative to improve n-3 fats. Flaxseed and canola are vegetable sources rich in n-3 fats, in the form of alpha linolenic acid (18:3n-3, ALA). Through this strategy, it is hoped that laying hens can convert ALA to n-3 LCPUFA, including EPA, DPA, and DHA (Kartikasari *et al*., 2021). Previous studies found that feeding flaxseed up to the 10% level tends to limit the effectiveness of increasing the n-3 fat levels (Al-Nasser *et al*., 2011). This finding is confirmed by Elkin and Harvatine (2023) that there is a reduction in the conversion/ transfer efficiency of dietary ALA to yolk n-3 LCPUFA with the increase in the levels of dietary ALA in laying hens given varying amounts of whole or ground flaxseeds or an extruded flaxseed product. It has been proposed that a saturation of activity of hepatic desaturase enzymes involved in ALA metabolism explains why there is a decreased conversion of ALA to n-3 LCPUFA with higher dietary ALA levels (Cachaldora *et al*., 2008).

Additionally, because there is competition between n-3 fats (ALA) and n-6 fats (LA) for the utilization of the same enzyme in metabolic pathways, a diet high in LA can inhibit the generation of DHA. As reported by Elkin *et al*. (2018), chickens can hepatically synthesize EPA and DHA from ALA; however, dietary linoleic acid (LA) inhibits the process and makes it ineffective. Study result of Kartikasari *et al*. (2021) showed, although dietary ALA remained constant, the amounts of EPA and DHA in broiler tissue reduce as the amount of LA in the diet increased. This indicates that the LA to ALA ratio of the diets determines the accumulation of n-3 fats in the chicken tissues. The supplementation of plant oils rich in ALA in basal diet against a background of low LA levels results in the significant deposition of n-3 LCPUFA and total n-3 fats both in chicken meat (Kartikasari *et al*., 2012) and eggs (Kartikasari *et al*., 2021) while maintaining the sensory quality of the products.

Regarding how strain affects the n-3 content of eggs, there is significant debate. Scheideler *et al*. (1998) claimed that the strain of hen had no significant impact on the deposition of DHA in the yolk of eggs. In contrast, some researchers have found that eggs from brown chickens fed ALA-rich diets had a higher accumulation of n-3 LCPUFA (Ahn *et al*., 1995). It is unclear why this is the case. The utilization of ALA-rich plants oils in various breeds of laying hens is not well understood. Thus, the purpose of this current research was to evaluate the impact of the dietary inclusion of n-3 fats (ALA) while maintaining LA on the accumulation of n-3 fats and the sensory properties of eggs.

MATERIALS AND METHODS

Animal Ethics

The approval of animal ethics for this research was given by the Animal Ethics Committees of the University of Adelaide and the Department of Primary Industries South Australia (Project Number H-071-2010). All procedures followed the "Australian code of practice for the care and use of animals for scientific purpos-

es" (Australian Agriculture Council, 1997) and the "Australian model code of practice for the welfare of animals Domestic Poultry" (Standing Committee on Agriculture and Resource Management, 1995).

Birds, Rearing, and Management

This study used a 3 x 2 factorial, completely randomised block design with eight replications for each strain and diet combination. Dietary interventions were focused on dietary ALA levels combined with constant LA levels. The chickens were housed at the Pig and Poultry Production Institute, the University of Adelaide, and the sensory properties of eggs were conducted at the Sensory Evaluation Laboratory. The chickens were raised using the methods outlined by Kartikasari *et al*. (2021). A total of 24 Hy-Line brown and 24 Hy-Line white were divided among the three experimental diets. The laying hens were given a 16-hour light schedule during their development phase.

Diets

The experimental diets were based on a diet of laying hen that had been carefully formulated (Ridley Agriproducts Pty Ltd, SA, Australia) to contain a low level of LA and varied doses of ALA. The experimental diets were made by supplementing pure or mixed pant oils to a base diet. The ALA levels of Macadamia, Canola, and flaxseed oil were 0.5, 9.4., and 47%, respectively (Table 1). The basal diet included 37.78% LA and 4.55% ALA. Apart from fatty acid composition, all dietary treatments had the same nutritional specifications. All diets met the specifications suggested for layer hens by the National Research Council (1994). The fat content was maintained at 8% (w/w). Dietary ALA concentrations were either from 0.3, 3.0, or 6.0%en, but LA levels remained stable at about 4%en (Table 2). Therefore, the LA to ALA ratio varied, ranging from low ALA diet (7.5:1) to high ALA diet (0.7:1).

Egg Sample Collection

Throughout the trial, daily egg production data was collected and converted to hen-day egg production. The weight of albumen and yolk were then measured after each egg from each hen was broken to separate the yolk. To analyse the fatty acid content of the egg yolk, a total of 48 egg yolks laid at week 12 (n = 8 yolks for each experimental diet) were kept at -20°C. Using eggs laid during week 13, the sensory qualities of scrambled eggs were assessed.

Fatty Acid Analysis

Following the method described by Folch *et al.* (1957), the total fat was extracted from egg samples and fatty acids methyl ester (FAME) was prepared following the method of previous studies (Kartikasari *et al.*, 2021) using 1% H_2SO4 in methanol (for 3 hours at 70°C). Then,

Table 1. Oil proportion of dietary treatments for the study period

Ingredients (%)	ALA (%)	Dietary treatments		
		Low ALA	Moderate ALA	High ALA
Basal diet[1]		94	94	94
Oil supplemented				
Macadamia oil	0.5	6.0	0.0	0.0
Canola oil	9.4	0.0	3.6	0.0
Flaxseed oil	47	0.0	2.4	6.0
Total		100	100	100

[1]The composition of basal diet consisted of (%): peas fine (20.00), wheat fine (19.20), triticale fine (19.73), barley (15.00), soybean meal (5.53), canola meal expeller (3.00), meat meal (2.30), wheat mill vits (0.80), limestone large (9.38), millrun (3.90), sodium bicarbonate (0.18), salt (.16), monodicalcium phosphate (0.26), alimet (0.24), choline chloride 75% (0.06), Ronozyme P 5000 Layer (0.009), Avizyme 1210 (0.003), Roxaphyll 112 (0.005), layer/pullet premix (0.20). The basal diet contained 37.78% LA and 4.55% ALA.

the resultant FAME was extracted with n-heptane and were kept at -20°C.

fatty acid

The fatty acid profiles of the egg samples were determined using a Hewlett-Packard 6890 GC, CA, USA and were identified using the methods published in a previous study (Kartikasari *et al.,* 2012). By proportionally comparing the peak areas of the gas chromatography to the internal standard (triheptadecanoic acid; 17:0), fatty acid concentrations were determined.

Descriptive Analysis Sensory Evaluation of Eggs

Panellist Selection and Training

Participants for the panel were chosen from among University of Adelaide students and employees who had no egg allergies and were prepared to eat eggs. There were ten panellists (n = 10) who took part in the scrambled eggs evaluation. The University of Adelaide's Human Ethics Committee in Australia had authorized the sensory evaluation procedure. After being briefed on the specifics of the experiment, each panellist signed a permission form. Four two-hour sessions of training were held for the chosen panellists. The objectives of this training were to improve the panellists' capacity to identify between samples of standard aroma, taste, and flavour. The training session also reviewed egg sensory methods and techniques. Consensus was achieved through discussion regarding the terminology of the attributes to be evaluated and low and high intensity standards (Table 3).

Sample Preparation

Prior to usage, the eggs were taken and chilled at 4°C for a week. On the evaluation day, scrambled eggs were made in the following manner: a total of 21 eggs were broken and eggs from each experimental diet were vigorously blended with a mixer (four seconds), resulting in a thin froth. Eight plastic containers are filled with one part (25 ml), which is then immediately placed into a nonstick saucepan that has been warmed. Two minutes were used to prepare the scrambled eggs. After that, the stove was turned off and the scrambled eggs were left on the heated stove for four minutes. The cooked eggs were taken out of the oven when they reached a temperature of at least 80ºC. There was no salt added, plant oil, or cooking spray to the scrambled eggs. Then, the small pieces were put in a closed bag made of plastic with random three-digit numbers on it. Then, they were put in a hot oven at 40°C to stay warm until they were ready to be

Table 2. The profiles of fatty acid of dietary treatments

Diets	Dietary treatments[2]		
	Low ALA (0.3)	Moderate ALA (3)	High ALA (6)
LA, %en	2.30	4.40	4.40
ALA, %en	0.30	3.20	6.20
Ratio of LA:ALA	7.50	1.40	0.70
Fatty acids, %[1]			
Total SFA	18.4 ± 0.04	13.7 ± 0.02	15.7 ± 0.02
Total MUFA	66.8 ± 0.09	42.3 ± 0.13	24.3 ± 0.02
LA	12.8 ± 0.11	25.1 ± 0.08	24.9 ± 0.03
Total n-6 PUFA	12.9 ± 0.11	25.2 ± 0.08	24.9 ± 0.03
ALA	1.7 ± 0.04	18.5 ± 0.05	34.8 ± 0.06
Total n-3 PUFA	1.8 ± 0.04	18.6 ± 0.05	34.9 ± 0.06
Total PUFA	14.6 ± 0.12	43.8 ± 0.12	59.8 ± 0.03

[1]MUFA= monounsaturated fatty acid; SFA= saturated fatty acid; PUFA= polyunsaturated fatty acid; ALA= alpha-linolenic acid; LA= linoleic acid.

[2]Kartikasari *et al*. (2021).

Table 3. Descriptive terminology and definitions used by trained panellists to assess scrambled eggs

Sensory attributes	Definition[1]	Scale anchors[2]	Reference standards
Aroma			
Egg aroma	Aroma typically associated with cooked egg	Low to intense	Low egg aroma (scrambled eggs; yolk:albumen =1:7) to high egg aroma (scrambled eggs; yolk:albumen =7:1)
Sulphur	Aroma associated with products containing sulphur: e.g. eggs	Low to high intensity	Low to high intensity for scrambled eggs (2 and 5 µg/L) hydrogen sulphide (H_2S) in distilled water
Butter	Aroma associated with unsalted butter	Low to high intensity	Butter: at room temperature
Off-odour	The presence of something disagreeable differing from the typical egg odour	No off-odour to strong off-odour	
Taste			
Salt	Fundamental taste sensation of which sodium chloride is typical	Low to high intensity	None to medium to high (0, 1.0, and 2.0 g/L sodium chloride in distilled water)
Sour	The taste associated with acid (citric acid in solution)	Low to high intensity	None to medium to high (0, 0.1, and 0.15 g/L citric acid in distilled water)
Sweet	Basic taste sensation of which sucrose is typical	Low to high intensity	Low to medium to high (2.5, 5, and 7.5 g/L sucrose in distilled water)
Aftertaste	The flavour sensation that lingers on the tongue and palate at 5 seconds after swallowing	Low to high intensity	
Flavour			
Egg flavour	Flavour typically associated with cooked egg	Low to intense	
Sulphur flavour	Flavour associated with products containing sulphur	Low to high intensity	
Butter flavour	Flavour associated with unsalted butter	Low to high intensity	
Off-flavours	The presence of something disagreeable differing from the typical egg flavour	No off-flavour to strong off-flavour	

[1]The descriptive terminology and definitions used were adapted from Parpinello *et al*. (2006) and Lawlor *et al.* (2010)
[2]A 15cm line-scale with indented anchor points of attribute intensity

eaten.

Descriptive Analysis Evaluation

Each panellist rated the aroma, taste, and flavour of samples of scrambled eggs from six distinct treatment groups (combinations of three diets and two strains). Each of the six treatments had three replications. A total of 18 samples of scrambled eggs were reviewed by the panellists. The panellists were asked to rate their impression of each attribute on unstructured 15-cm line scales (Figure 1) with anchors at both ends, at 10 and 90% (Bastian *et al.*, 2010; Kartikasari *et al.*, 2021). The panellists were encouraged to smell and taste while the qualities reference standards were available to them. Additionally, panellists

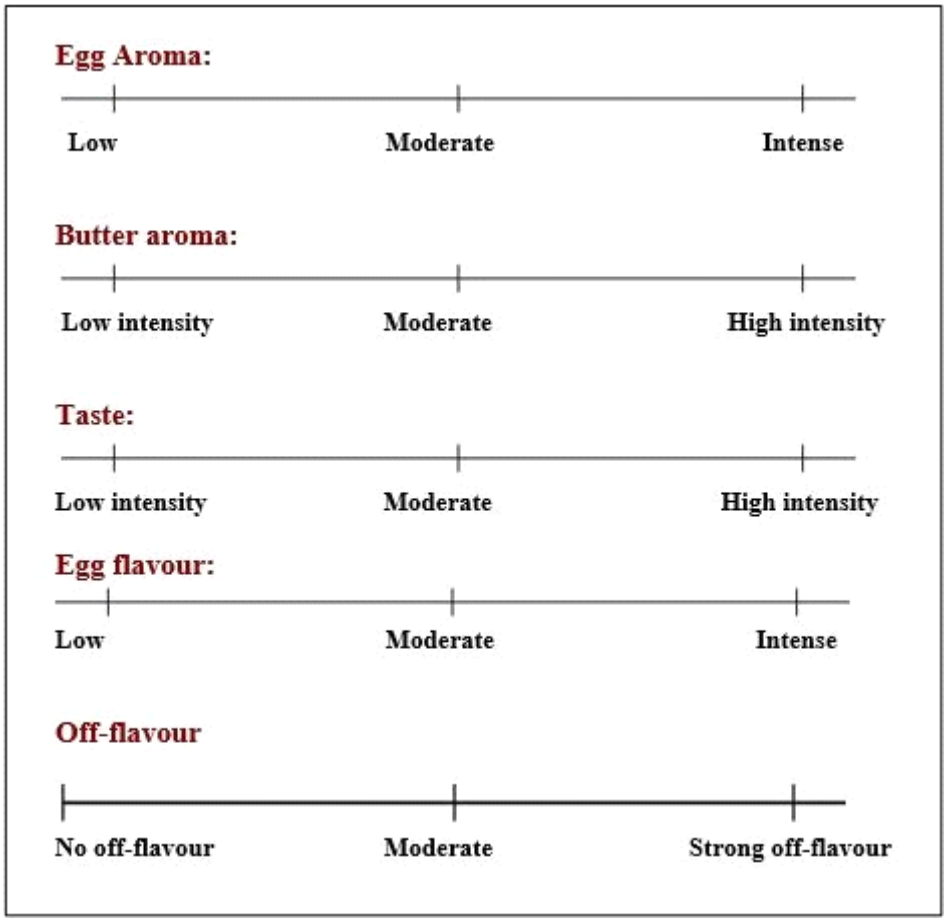

Figure 1. Examples of the line scales used in the assessment of scrambled egg samples

were urged to submit comments on the significant variations in the scrambled eggs offered. Sensory assessment was done in customary booths arranged individually with yellow lighting to prevent visible discrepancies in yolk colour. Each panellist received samples as well as criteria for fragrance and taste in the booths. Using FIZZ software version 2.47b, the data were collected after panellists evaluated the samples using computerized scales. Unsalted crackers and water were given as palate cleansers. Then, the panellists were given a mandatory one-minute break between eggs evaluated and were instructed to rinse the mouths after each sample. Panellists were provided with scrambled eggs in groups of six and for every six samples, panellists took a 10-minute break.

Statistical Analysis

Fatty acid profiles were analysed using GenStat (GenStat Release 14) and univariate ANOVA using a completely randomised block design. A Tukey's multiple comparison test was applied if significant differences across the dietary regimens were observed, and the significance threshold for families was set at $P< 0.05$. The data of sensory properties for each sensory characteristic was analysed in a univariate mixed linear model in GenStat (Release 14) using the ANOVA command. Differences in means of the treatments were examined further using Fisher's protected LSD. The number of assessor or pan-

ellists participating in the sensory evaluation was ten (n = 10) trained panellist.

RESULTS AND DISCUSSION

Fatty Acid Profiles

The goal of this study was to determine whether adding various doses of ALA to the diets of two breeds of hens would increase the content of n-3 fats in the eggs without impairing their sensory quality. Previous research has focused on the effects of ALA-supplemented meals on the fatty acid profiles and production metrics of white or brown laying hen strains (Nain *et al*., 2012). The fatty acid profiles of eggs from various breeds of chickens were also the subject of a small number of research (Ahn *et al*., 1995). However, there have not been any research on the sensory evaluation of eggs employing both strains of white and brown eggs given ALA-enhanced diets while preserving the LA level, nor have there been any data on the deposition of omega-3 fats. The amount of all n-3 LCPUFA, total n-3 fats, and total PUFA increased when ALA was added to the diet (Table 4). As dietary ALA levels improved, however, the MUFA and AA amount reduced ($P<0.001$). The level of PUFA enhanced by 2.8-fold ($P<0.001$) when the amount of ALA in diets increased from 0.3 to 6%en, primarily at the expense of monounsaturated fatty acid content ($P<0.001$). The DPA level in the eggs enhanced by almost three times ($P<0.001$) after ALA was added to laying hen diets compared to controls. However, the amount of egg DPA did not considerably rise when the amount of ALA was increased from 3 to 6%en. Hens fed dietary enrichment of ALA at levels of 3 and 6%en produced eggs that contained higher DHA level ($P<0.001$) compared to laying hens fed diets with ALA at a level of 0.3%en (which is comparable to the ALA level in commercial diets). The eggs from chickens fed dietary treatments supplemented with ALA at 3 and 6%en levels had a two-fold increase in DHA content. The enrichment in ALA, which rose by roughly 40-fold, was primarily responsible for the rise in n-3 PUFA (Table 4). At day 56, the total n-3 level of the eggs laid by hens given diets containing 3 and 6%en ALA was five- and ten-fold greater, respectively, than that of hens fed a diet low in ALA ($P<0.001$).

The results demonstrate a significant association between dietary ALA levels and egg n-3 content, particularly in the form of ALA and n-3 LCPUFAs. This result supports the idea that n-3 fat intake directly affects the kind of fat deposited in egg yolks and that the fatty acid composition of the egg yolk may be modified to varying degrees by altering the composition of the diet's dietary fats. In particular, the ability of laying hens to convert ALA into DHA (Ehr *et al*., 2017). When diet high in ALA was applied, the level of n-3 LCPUFA increased. This provides evidence of a limited but effective conversion of ALA to n-3 LCPUFA (Zhang *et al*., 2017). These findings suggest that n-3 LCPUFA-rich eggs may be produced when plant oils rich in ALA are given against a background of low levels of LA in baseline diets.

There may have been a maximum ALA level at which DHA could be converted. There was no additional increase in DHA content for the levels of dietary ALA over 3%en, and the greatest level of DHA (1.7%) was obtained when the laying hens were given diet at 3%en ALA. These results are in line with studies showing that DHA production is inhibited by diets rich in PUFA, including both ALA and LA (Gibson *et al*., 2013). To more accurately define the ideal quantity of dietary ALA, other research with greater quantities of ALA should be conducted. Additionally, competition between the LA and ALA for desaturase in the synthetic route could not be used to explain any favourable response in the deposition of DHA by improving dietary ALA levels (Nain *et al*., 2012; Kartikasari, 2021). The deposition of n-3 LCPUFA levels (EPA and DHA) improved by increasing levels of dietary ALA while keeping dietary LA in a low level (Kartikasari *et al*., 2012), as reported by Kartikasari *et al*. (2021), who found that improving levels of dietary LA decreased the n-3 LCPUFA accumulation in chicken tissue. These results are consistent with earlier research that

Table 4. Fatty acid composition of eggs[1]

ALA (%)	0.3		3.0		6.0			P value[2]		
Strains	white	brown	white	brown	white	brown	SEM	D	S	D x S
Fatty Acids (%)[3]										
16:0	17.5	16.2	17.8	16.2	18.1	16.7	0.31	NS	**	NS
18:0	5.2^{c}	6.3^{b}	6.5^{b}	6.5^{b}	7.2^{a}	7.3^{a}	0.15	**	**	**
Total SFA	22.9^{bc}	22.8^{c}	24.5^{ab}	22.8^{c}	25.5^{a}	24.2^{abc}	0.36	**	**	NS
18:1n-9	41.5	42.6	36.8	36.8	31.4	33.3	0.35	**	**	NS
Total MUFA	50.3	51.5	41.1	41.4	35.5	37.5	0.37	**	**	NS
Total n-9	42.8^{a}	44.2^{a}	37.8^{b}	38.1^{b}	32.1^{c}	34.3^{c}	0.37	**	**	*
LA	6.2	5.3	11.2	11.0	11.3	11.3	0.25	**	NS	NS
AA	1.4^{a}	1.2^{a}	0.8^{b}	0.8^{b}	0.6^{c}	0.6^{c}	0.04	**	*	*
Total n-6	8.1	7.0	12.2	12.0	12.0	12.0	0.27	**	*	NS
ALA	0.2	0.2	3.8	3.8	8.0	8.1	0.18	**	NS	NS
EPA	0.0	0.0	0.1	0.1	0.2	0.2	0.01	**	NS	NS
DPA	0.1	0.1	0.2	0.3	0.3	0.3	0.02	**	*	NS
DHA	0.8^{c}	0.6^{c}	1.5^{b}	1.7^{a}	1.4^{b}	1.5^{b}	0.05	**	*	**
Total n-3	1.1	0.9	5.6	6.0	10.0	10.2	0.20	**	NS	NS
Total PUFA	8.0	7.9	17.8	17.9	22.0	22.2	0.60	**	NS	NS
LA:ALA ratio	28.5	31.6	2.9	2.9	1.4	1.4	0.75	**	NS	NS

[1]Values are means of eight replications per dietary treatment with pooled SEM.
[2]NS= not significant; *= P<0.05; **= P<0.01, D= diet, S= strain, D x S= interaction between diet and strain.
[3]MUFA= monounsaturated fatty acid; SFA= saturated fatty acid; PUFA= polyunsaturated fatty acid; ALA= alpha-linolenic acid; LA= linoleic acid; AA- arachidonic acid; EPA= eicosapentaenoic acid; DPA = docosapentaenoic acid; DHA = docosahexaenoic acid.

discovered a maximum DHA level may be attained by consuming more dietary ALA (Sari *et al*., 2002). Given that these authors did not disclose the ALA level of the diets; it is challenging to compare these findings to those of the current research. However, Grobas *et al*. (2001) showed that adding linseed oil to eggs in amounts ranging from 5 to 10% did not alter the DHA level of the eggs, which is consistent with the findings of the present investigation. This result was supported by a prior work that reported egg fatty acid content in mg/egg yolk (Kartikasari *et al*., 2021). With ALA-enriched feed, ALA, n-3 LCPUFA, and total n-3 were accumulated higher, and it appears that the rise in ALA, EPA, DPA, and total n-3 happened linearly (P<0.01). However, laying hens given a moderate ALA diet exhibited the greatest DHA levels (87 mg/egg yolk), indicating that the DHA content in eggs had peaked.

We observed a somewhat greater DHA deposition in eggs than Grobas *et al*. (2001), who also utilized flaxseed oil. The disparate outcomes might be attributed to the low LA level in the basal diet or the fact that the amount of LA in the moderate (3.0%en) and high ALA (6.0%en) diets was kept constant. It is widely known that LA and ALA compete with one another to use the same desaturase and elongase enzymes for the bioconversion into n-3 LCPUFA. According to Kartikasari *et al*. (2021), a larger intake of LA may lessen the deposition of n-3 LCPUFA in chicken tissues.

When compared to white laying chickens, brown hens produced significantly higher MUFA, DPA, and DHA (P< 0.001, Table 4). In contrast, white hens accumulated more SFA than brown hens (P<0.001). Regarding how strain affects the fatty acid content of eggs, there is significant debate. Scheideler *et al*. (1998) claimed that the hen strain had no appreciable impact on the accumulation of ALA or DHA in

Table 5. Sensory assessment of scrambled eggs from brown and white laying hens fed diets containing alpha-linolenic acid.

ALA Level (%)	0.3	3.0	6.0		Low (0.3)		Moderate (3.0)		High (6.0)			P Value[2]				
Strains				SEM	White	Brown	White	Brown	White	Brown	SEM	Diet	Strain	D x S	Assessor	A x T
Sensory Attributes[1]																
Aroma																
Egg aroma	9.55^{a}	9.45^{a}	8.79^{b}	0.13	9.34^{bc}	9.77^{ab}	8.79^{cd}	10.10^{a}	8.65^{d}	8.93^{cd}	0.19	**	**	*	***	NS
Oily odour	1.20	1.33	1.41	0.12	1.14	1.25	1.24	1.42	1.24	1.58	0.16	NS	NS	NS	***	NS
Butter aroma	4.89	5.17	5.07	0.31	4.44	5.35	5.03	5.32	5.18	4.97	0.44	NS	NS	NS	***	NS
Sulphur aroma	6.33	6.92	7.37	0.37	5.71	6.94	6.75	7.08	7.59	7.15	0.53	NS	NS	NS	***	*
Taste																
Sweet taste	3.59	3.37	3.50	0.19	3.36	3.81	3.42	3.32	3.66	3.34	0.27	NS	NS	NS	***	NS
Sour taste	3.12	3.14	3.30	0.12	3.18	3.07	3.22	3.06	3.43	3.17	0.16	NS	NS	NS	***	NS
Salty taste	6.98	6.86	7.06	0.23	6.52	7.43	6.93	6.79	7.10	7.01	0.33	NS	NS	NS	***	NS
Aftertaste	6.18	6.48	6.52	0.23	6.32	6.04	6.76	6.21	6.38	6.66	0.32	NS	NS	NS	***	*
Flavour																
Butter flavour	4.09	4.34	4.29	0.17	3.72^{b}	4.46^{a}	4.07^{b}	4.61^{a}	4.24^{b}	4.34^{a}	0.24	NS	*	NS	***	NS
Sulphur flavour	5.80^{b}	6.80^{a}	6.96^{a}	0.23	5.52^{b}	6.08^{a}	6.61^{b}	6.98^{a}	6.45^{b}	7.47^{a}	0.33	**	*	NS	***	NS
Egg flavour	7.93	8.24	7.88	0.23	7.95	7.91	7.84	8.64	7.44	8.32	0.33	NS	NS	NS	***	NS
Off-flavour	1.06	1.24	1.09	0.09	1.07	1.05	1.11	1.38	1.14	1.04	0.13	NS	NS	NS	***	NS

[1]Scores are means of three replications for each treatment and the pooled SEM evaluated by 10 panellists.
[2] NS = not significant; *= P<0.05; **= P<0.01; ***= P<0.001; S = strain; D = diet; A = assessor; T = treatment

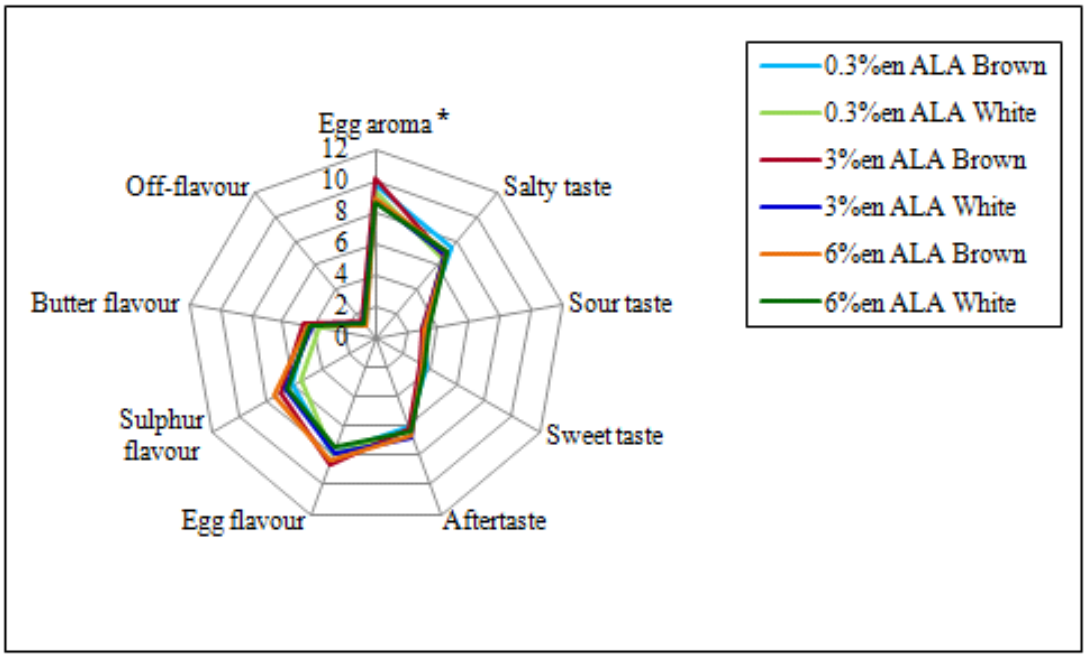

Figure 2. Mean scores of sensory characteristics of scrambled eggs from brown and white hens fed dietary treatments rich in ALA (0.3, 3.0, and 6.0%en). There was a significant interaction between diet and strain of hens. Experimental diets high in ALA (6.0%en) caused a decrease in egg aroma in white scrambled eggs.

the egg yolk. On the other hand, some researchers have found that eggs from brown chickens given ALA-rich diets had a higher buildup of n-3 LCPUFA (Ahn *et al*., 1995). Although the causes of this are unknown, it appears likely that we may draw the conclusion that brown layers are more effective in converting ALA to n-3 LCPUFA.

There was an interaction between dietary treatments and strains of hens ($P<0.05$) on egg AA level. Increasing levels of dietary ALA reduced AA to greater extent in white laying hens than brown laying hens. It is noteworthy to note that for the deposition of DHA in egg yolks, a substantial relationship between ALA levels and hen strains was discovered. The interactive effect of strains and diets on DHA accumulation was such that diets containing 3%en ALA increased DHA level, and the effect was more responsive in brown hens than in white hens. The eggs produced by brown chickens on a diet containing 3%en of ALA have the greatest DHA content (1.7%). Accordingly, brown laying hens on diets with ALA of 3%en had greater levels of total n-3 LCPUFA than white laying chickens. To produce eggs that are higher in n-3 LCPUFA, which is essential for human health, brown laying hens may be administered dietary ALA at a level of 3%en, according to this research. This dietary approach might also provide people a different source of n-3-rich diet.

Sensory Properties of Scrambled Eggs

Table 5 and Figure 2 show the average results for the characteristics of scrambled eggs. No difference ($P>0.05$) was seen in the taste, aftertaste, egg flavour, butter flavour, or off-flavour of scrambled eggs when ALA levels were increased in the diet. The samples of scrambled eggs from hens given diets high in ALA (6%en) had the lowest grade in terms of egg aroma (average intensity score of 8.79).

The average intensity score for the sulphur flavour in scrambled egg samples from diets containing 0.3%en ALA was lower than that of ALA -supplemented diets (scores of 6.80 and 6.96, respectively). However, there were no changes between the moderate and high ALA diets in terms of this attribute's sensory panel ratings. One of the most important quality factors in in-

fluencing consumer acceptability of any food item is sensory attributes. The crucial n-3 LCPUFA have been reported to increase when marine sources are added to the diets of laying hens; however, such diets significantly reduce the sensory quality of eggs, including the fishy off-flavour of the eggs (Lawlor *et al*., 2010). This may be caused by trimethylamine (TMA), the presence of lipid oxidation products, variations in volatile concentrations in n-3 fatty acid-enriched eggs, the techniques of egg preparation (Van, 1997), or the presence of lipid oxidation products. When laying hens were given diets rich in flaxseed either as ground flaxseed or whole flaxseed (10%), adverse sensory characteristics in the eggs were also documented (Caston *et al*., 1994), and this resulted in the decrease acceptability of the eggs (Scheideler *et al*., 1997). The level of DHA and total n-3 LCPUFA in this research, however, was quadrupled by diets enhanced with ALA sources in the form of plant oils, without altering the sensory characteristics of the eggs. According to reports, giving hens a flaxseed diet caused off-flavour in their eggs. However, in this study, panelists found no difference for off-flavour in eggs from chickens fed high ALA diets versus low ALA diets. Because the egg storage conditions before sensory evaluation and the egg processing method in this study were similar to those in studies incorporating flaxseed into the diet (Leeson *et al*., 1998), this difference may be due to differences in the type of fat in the diet sources used, were whole or ground flaxseeds versus flaxseed oil (Jiang *et al*., 1992) or the level of ALA sources present in the diet (Kartikasari *et al*., 2021).

Brown eggs had slightly higher perceptions ($P<0.05$) of egg aroma, sulphur flavour, and butter flavour than white eggs. Diets high in ALA slightly reduced egg aroma in white scrambled eggs, indicating a significant interaction between diet and strain. These discrepancies might be attributed to brown eggs having a greater n-3 LCPUFA content, specifically DPA and DHA, than white eggs. Previous investigations have found variations in sensory features among strains in terms of flavour ratings (Ahn *et al*., 1995).

CONCLUSION

The results of the study show that n-3 PUFA, ALA derived from plant oils can be added to commercial hen diets up to a level of 6%en ALA without influencing the sensory qualities of the eggs, and that the dietary inclusion of 3%en ALA was found to be optimum in relation to the accumulation of n-3 fatty acids and the sensory characteristics of the products. It was discovered that brown laying hens were more successful at converting ALA to n-3 LCPUFA and, as a result, deposited more DPA and DHA compared to white chickens. Based on this knowledge, the use of ALA level of 3%en could be suggested as an appropriate ALA level for generating n-3 LCPUFA-enriched eggs by the chicken industry; however, more research is required to determine the optimal amount.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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