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Effect of production system, supermarket and purchase date on the vitamin D content of eggs at retail

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ABSTRACT

The vitamin D content of eggs from three retail outlets was measured over five months to examine the effects of production system (organic vs. free range vs. indoor), supermarket and purchase date on the concentration of vitamin D_3 and 25-hydroxyvitamin D_3. Results demonstrated a higher vitamin D_3 concentration in free range (57.2 ± 3.1 μg/kg) and organic (57.2 ± 3.2 μg/kg) compared with indoor (40.2 ± 3.1 μg/kg) ($P < 0.001$), which was perhaps related to increased vitamin D synthesis by birds having more access to sunlight, while 25-hydroxyvitamin D_3 concentration was higher ($P < 0.05$) only in organic eggs. The interaction ($P < 0.05$) between system and supermarket for both forms of vitamin D may relate to some incorrect labelling. Concentration of 25-hydroxyvitamin D_3 was higher ($P < 0.05$) in July and September than in August. The results indicate variations in vitamin D concentrations in eggs from different sources, thus highlighting the importance of accurate labelling.

1. Introduction

The two major sources of vitamin D for humans are *in vivo* synthesis by exposure to sunlight and dietary intake. Holick and Chen (2008) reported the links of vitamin D deficiency with increased risk of many common and serious diseases, such as cardiovascular disease, osteoporosis, common cancers and diabetes, in addition to its association with calcium homeostasis. Maintaining a serum 25-hydroxyvitamin D (25(OH) D) concentration of at least 75 nmol/L is regarded as being necessary for prevention of most vitamin D-related diseases (Vieth, 2011). There are many factors which limit *in vivo* synthesis of vitamin D via ultraviolet radiation, such as a more indoor lifestyle, latitude, skin pigmentation, ageing and sunscreen use (Holick, 1995). Thus, the prevalence of vitamin D deficiency in Europe has become a very concerning issue (Cashman et al., 2016). In the UK, a study showed that 87% of 7437 white British participants (92% Scotland residents) had plasma concentrations of 25(OH) D of below 75 nmol/L during winter and spring (Hypponen & Power, 2007). Therefore, the vitamin D intake from dietary sources has become more important in maintaining adequate vitamin D status. However, only certain foods (e.g. fish, meat, offal, eggs) are naturally rich in vitamin D (Schmid & Walther, 2013), and many of these are not consumed widely.

Eggs contain, not only vitamin D_3, but also significant quantities of 25-hydroxyvitamin D_3 (25(OH) D_3) (Mattila, Piironen, Uusi-Rauva, & Koivistoinen, 1993; Schmid & Walther, 2013), with the accumulation of vitamin D in the egg yolk rather than egg white (Fraser & Emtage, 1976). Studies have shown that the 25(OH) D_3 metabolite is five times more effective at raising plasma 25(OH) D_3 concentration in humans and has been reported to be absorbed at a faster rate when compared with an equivalent dose of vitamin D_3 (Cashman et al., 2012; Jetter et al., 2013).

Recently, the vitamin D concentration of whole eggs was given as 3.2 μg/100 g in the UK official food database (McCance & Widdowson, 2015). Eggs are available from different husbandry production systems, including indoor, free-range and organic in the UK retail outlets (Department for Environment & Rural Affairs, 2010). Evidence from a previous enhancement study demonstrated that vitamin D in eggs was increased from birds exposed to ultraviolet radiation (Kühn, Schutkowski, Kluge, Hirche, & Stangl, 2014). Thus, vitamin D concentrations of eggs may vary due to different production systems which give the birds varying lengths of sunlight exposure. However, there are limited data on the vitamin D content of retail eggs from the different UK production systems. As customers will expect more expensive eggs to be of better quality, it is important to inform the consumer about the effect of different production systems on the nutritional

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composition of eggs. One previous UK study suggested that the vitamin D_3 concentration of hens' eggs was significantly affected by housing system, with the vitamin D_3 content of egg yolk produced outdoors being significantly higher (44.1–69.2 nmol/L) than that of egg yolk produced indoors (17.3–18.7 nmol/L) (Hobbs-Chell, Stickland, & Wathes, 2010). However, egg yolk 25 (OH) D_3 concentration was not reported, and the study was not concerned with retail eggs.

The main objective of the current study was to explore the effects of production system (as labelled), supermarket and time of the year on the concentrations of vitamin D_3 and 25(OH) D_3 in the egg yolk from UK hens' eggs at retail. Although variation in vitamin D_3 content of eggs collected from UK farms due to production system has been reported (Hobbs-Chell et al., 2010), the data are unlikely to reflect eggs currently in the UK market. Accordingly, the current study focussed on the effect, not only of labelled production system, but also on supermarket and seasonal variation of two forms of vitamin D, vitamin D_3 and 25(OH) D_3 in UK retail eggs. This study also updates information on the vitamin D_3 and 25(OH) D_3 contents of eggs sold in the UK, which may improve the estimation of the contribution of eggs to vitamin D intakes of the general population.

2. Materials and methods

2.1. Sample collection

Eggs were purchased from three supermarkets (Supermarket 1, Supermarket 2, and Supermarket 3) in the Reading, Berkshire area, once per month, from July to November in 2012. On each occasion, packs of six eggs per box from three production systems (indoor, organic and free range, as identified on the label) were purchased from each supermarket, so a total of 270 eggs was collected. Following collection, eggs were transported directly to the laboratory, the yolks and whites of each egg were separated manually. The yolk was homogenised and decanted into 10 ml tubes before storage at −80 °C prior to vitamin D analysis. In total, 259 egg yolks (129 egg yolks for vitamin D_3 analysis; 130 egg yolks for 25(OH) D_3 analysis) were stored frozen, prior to analysis, as the egg whites and egg yolks of 11 eggs failed to separate during the processing. Nutritional information on the label of the purchased egg boxes was recorded for each sample.

2.2. Vitamin D_3 and 25(OH) D_3 analyses

The vitamin D_3 and 25(OH) D_3 concentrations of egg yolk samples were analysed by DSM Nutritional Products Ltd., (Basel, Switzerland). Vitamin D_3 analysis was carried out according to the method of Schadt, Gössl, Seibel, and Aebischer (2012).

The concentration of 25(OH) D_3 in the egg yolk samples was quantified by the standard method of the DSM Nutritional Products Ltd. using a LC-MS system (Agilent 1946). In brief, the sample was combined with d_6-25(OH) D_3 as an internal standard and the mixture dispersed in water. The suspension was extracted with tert-butyl methyl ether (TMBE). An aliquot of the TMBE phase was purified by semi-preparative normal-phase HPLC with a YMC-Pack-Sil column. An appropriate fraction was collected and analysed after solvent exchange by reversed-phase HPLC equipped with Aquasil C18 column and a mass selective detector.

2.3. Data analysis

A General Linear Model ANOVA (Minitab version 16; Minitab Inc., State College, PA, USA) was used to investigate the effect of (a) month of purchase (July to November 2012), (b) production system (indoor, organic or free-range) and (c) supermarket (S1, S2 or S3) on vitamin D_3 and 25(OH) D_3 concentrations. Tukey's pairwise multiple comparison test was used for *post hoc* analysis. Effects were considered significant when $P < 0.05$.

Total vitamin D concentration was calculated by using concentrations of vitamin $D_3 + (5 \times 25(OH)\ D_3)$ (McCance & Widdowson, 2015).

3. Results

3.1. Effect of production system

Concentrations of both vitamin D_3 and 25(OH) D_3 in egg yolk differed ($P < 0.001$), depending on production system (Table 1). Egg yolk from free range and organic systems contained a 42% greater concentration of vitamin D_3 than did those from the indoor system (Table 1). In addition, organic egg yolks had a higher ($P = 0.001$) concentration of 25(OH) D_3 than had egg yolks from free range and indoor systems, although no differences were observed between caged and free range systems.

3.2. Effect of purchase month

There was no effect of month purchased on the concentration of vitamin D_3 in egg yolks (Table 1; Fig. 1a). However, there was a significant effect of the system by month interaction ($P = 0.001$; Table 1), meaning that the vitamin D_3 concentration changes across different months varied by production system (Fig. 1a). The greatest ($P < 0.05$) concentration of vitamin D_3 in egg yolks tended to be found during summer months for indoor and organic eggs but, for free range eggs, the highest ($P < 0.05$) concentration was observed during the autumn months (Fig. 1a).

Month of collection had an effect ($P < 0.001$) on egg yolk 25(OH) D_3 concentration; however, as with vitamin D_3, no clear trend over time was observed (Fig. 1b). Again, a production system by month interaction was observed ($P = 0.001$; Fig. 1b). The lowest ($P < 0.05$) concentration of 25(OH) D_3 across all production systems was measured during August (Fig. 1b), but highest ($P < 0.05$) concentrations were observed during different months for each production system. In addition, no interaction ($P > 0.05$) was observed between supermarket and month on both vitamin D concentrations of the eggs.

3.3. Effect of supermarket

An effect of supermarket ($P = 0.009$) was observed for vitamin D_3 (Table 1; Fig. 2a) but not for 25(OH) D_3 (Table 1; Fig. 2b). The interaction effects of production system with supermarket were significant for both vitamin D_3 ($P < 0.001$) and 25(OH) D_3 ($P = 0.033$) (Table 1). For Supermarket 1, free range eggs were higher ($P < 0.05$) in vitamin D_3 concentration than were both caged and organic eggs. In addition, there was no interaction ($P > 0.05$) between supermarket and month for vitamin D_3 and 25(OH) D_3 (Table 1).

4. Discussion

4.1. General

The main objective of this study was to identify any differences in egg yolk vitamin D_3 or 25(OH) D_3 concentrations between three different production systems (indoor, free range and organic). To our knowledge, this is the first comparison study of both vitamin D forms between indoor and outdoor eggs from different UK retail supermarkets among varied months of the year.