Nutrient analysis of eggs

Summary report

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Description	This survey forms part of the Department of Health's rolling programme of nutrient analysis which provides up-to-date and reliable information on the nutrient content of foods. The results are incorporated into nutrient databanks which support the National Diet and Nutrition Survey and other national dietary surveys used to monitor the nations diet. Any data queries will be dealt with on a case by case basis.
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For Recipient's Use	

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Executive summary

A survey to determine the nutrient composition of eggs has been carried out to provide up-to-date nutrient data composition for chicken eggs. Changes in chicken feed and egg production methods since previous analysis suggested that nutrient content might also have changed.

This survey, carried out by a consortium led by the Institute of Food Research (and including Susan Church (Independent Nutritionist), British Nutrition Foundation, Laboratory of the Government Chemist and Eurofins Laboratories), forms part of the Department of Health's[1] rolling programme of nutrient analysis which provides up-to-date and reliable information on the nutrient content of foods[2]. The results from this programme of work are incorporated into the Department of Health's nutrient databanks which support the National Diet and Nutrition Survey and other national dietary surveys. These national surveys are used by Government to monitor the nation's diet. This programme of work to determine the nutrient composition of foods is key to ensuring that estimates of nutrient intakes from dietary surveys are robust. The results of this survey will also be incorporated into the Composition of Foods Integrated Dataset[3] and future publications of *McCance and Widdowson's The Composition of Foods* series.

8 composite samples made up of a number of different types of chicken egg were analysed for energy and a range of nutrients including fat, fatty acids (including *trans*), protein, and a full range of vitamins and minerals. Results of these analyses are published here.

A list of composite samples to be analysed was determined following consultation with the British Egg Industry Council (BEIC) and expert users of UK food composition data (including representatives of the food industry, academia, catering suppliers, nutritionists and dietitians). Market share information provided by BEIC was used to determine the sub-samples included within each composite sample.

Each composite comprised twelve sub-samples 50% of which were medium sized eggs and 50% large sized eggs of varying age. Enriched cage, barn, free range and organic eggs were included. Results show that current nutrient composition data for eggs is broadly similar to existing data from analyses carried out in the late 1980s although current levels of fat soluble vitamins D and E, and selenium appear to be higher. These results are consistent with known changes in egg production processes and chicken feed. These results also show that levels of total fat, fatty acids and cholesterol in whole eggs have reduced slightly. However, this is not the case for analysis of egg yolk only (the source of total fat, fatty acids and cholesterol in eggs). These lower levels therefore reflect changes in the ratio of egg yolk to egg white in whole eggs since eggs were last analysed (which is significantly associated with egg size and age of hens for example[4]).

Background

The Department of Health undertakes a rolling programme of nutrient analysis surveys to ensure that reliable, up-to-date information on the nutritional value of foods is available for use in conjunction with food consumption data collected in dietary surveys to monitor the nutritional content of the nation's diet. Therefore, these nutrient surveys need to provide a single, robust set of nutrient values that is indicative of the potentially broad choice available to the consumer when selecting any particular type of food. As a result, composite samples made up of a number of different types of chicken egg (enriched cage, barn, free range and organic) have been analysed for this survey rather than samples made up of single types.

The aim of this particular survey was to provide up-to-date nutrient composition data for chicken eggs to reflect changes in chicken feed and egg production methods.

Methodology

A list of composite samples to be analysed was determined following consultation with BEIC and expert users of UK food composition data (including representatives of the food industry, academia, catering suppliers, nutritionists and dietitians). Sub-samples included in composites were based on market share information provided by BEIC. To extend the scope of the survey BEIC funded the analysis of amino acids, vitamin A (retinol and carotenoids), vitamin D, vitamin E, vitamin K and choline.

Eggs were collected from three large regional packing centres between 22 and 25 March 2011 and prepared for analysis between 28 March and 14 April 2011. The eggs sampled included medium and large sized enriched cage, barn, free range and organic eggs of varying age.

The eggs were combined into 8 composite samples for analysis. Each composite was made up of 12 sub-samples of equivalent weight. This process allows a single, robust set of nutrient values to be derived for each composite. Sub-samples requiring preparation/cooking were prepared in accordance with guidelines produced by BEIC (http://www.eggrecipes.co.uk) and then combined into composite samples for analysis. Composites were analysed for proximates, individual fatty acids, amino acids and choline between May and July 2011, and analysed for inorganics and vitamins between May and September 2011. A full list of the composite food samples analysed is given in Annex A. The full sampling report is available at www.dh.gov.uk/publications.

Each composite sample was analysed for energy and a range of nutrients including protein, total fat, fatty acids and a full range of vitamins and minerals depending on the importance of eggs as a dietary source for each nutrient, and existing compositional data available. A full list of nutrients is given in Annex B. The methods used to conduct the analyses are included at Annex D.

Values provided by analytical laboratories were compiled in Excel spreadsheets for data evaluation. Where possible, analytical values were compared to other sources of comparable data, such as UK Food Composition tables, other food composition tables and information from manufacturers and retailers. Where analytical values appeared incorrect or questionable, data was checked against original laboratory reports and re-analysed if necessary.

Results

Each of the composite samples was analysed for an extensive range of nutrients, and therefore this project generated a large number of individual results. A summary of results for energy, protein, fat and fatty acids, fibre and cholesterol, vitamins and minerals is provided in Annex C. The full set of results are provided in the analytical report associated with this project which is available at www.dh.gov.uk/publications.

Each composite comprised twelve sub-samples 50% of which were medium sized eggs and 50% large sized eggs of varying age. Enriched cage, barn, free range and organic eggs were included. Results show that current nutrient composition data for eggs is broadly similar to existing data from analyses carried out in the late 1980s although current levels of fat soluble vitamins D and E, and selenium appear to be higher. These results are consistent with known changes in egg production processes and chicken feed. These results also show that levels of total fat, fatty acids and cholesterol in whole eggs have reduced slightly. However, this is not the case for analysis of egg yolk only (the source of total fat, fatty acids and cholesterol in eggs). These lower levels therefore reflect changes in the ratio of egg yolk to egg white in whole eggs since eggs were last analysed (which is significantly associated with egg size and age of hens for example[4]).

Interpretation

This survey has determined the nutrient composition of eggs. Changes in chicken feed and egg production methods since previous analysis suggested that nutrient content might also have changed.

The results from this survey provide us with robust, up-to-date data, which will be incorporated into the Department of Health's nutrient databanks which support our National Diet and Nutrition Survey and other national dietary surveys enabling the Government to monitor the nation's diet.

The results of this survey will also be incorporated into future publications in the *McCance and Widdowson's The Composition of Foods* series.

Further Information

The report of this survey (entitled Nutrient analysis of eggs) is available at www.dh.gov.uk/publications.

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Annex A: Details of composite samples analysed

Sample	Food Group
1	Eggs, chicken, whole, raw
2	Eggs, chicken, white, raw
3	Eggs, chicken, yolk, raw
4	Eggs, chicken, whole, boiled
5	Eggs, chicken, white, boiled
6	Eggs, chicken, yolk, boiled
7	Eggs, chicken, whole, poached
8	Eggs, chicken, whole, fried in sunflower oil

Annex B: List of nutrients analysed

Proximates	Water Protein (nitrogen and nitrogen factor) and amino acids* Fat Dry Ash content
Fatty acids	Individual fatty acids (*cis* & *trans* isomers, positional isomers, branched chain) (expressed as percentage total fatty acids and per 100g food)
Sterols	Cholesterol
Carbohydrate	(All expressed as monosaccharide equivalents) Starch, total sugars, total carbohydrate, glucose, fructose, sucrose, maltose, lactose, galactose Oligosaccharides
Fibre	As non-starch polysaccharide i.e. Englyst method, and AOAC method
Inorganics	Sodium, potassium, calcium, magnesium, phosphorus, iron, copper, zinc, chloride, manganese, iodine, selenium
Water soluble vitamins	Thiamin, riboflavin, niacin, tryptophan (to calculate niacin equivalent), vitamin B_6, vitamin B_{12}, folate, pantothenic acid, biotin, vitamin C
Vitamin A*	Retinol, carotenoids (alpha-carotene, beta-carotene, cryptoxanthins)
Other carotenoids	Lutein, lycopene, zeaxanthin
Vitamin D*	Vitamin D_3, 25-OH vitamin D
Vitamin E*	Alpha-tocopherol, beta-tocopherol, delta-tocopherol, gamma-tocopherol, alpha-tocotrienol, gamma-tocotrienol
Vitamin K*	Vitamin K_1, vitamin K_2
Choline and Choline chloride*	

*Funded by BEIC

Note: Each of the samples was analysed for a range of nutrients in the above list, depending on existing compositional data available and the importance of eggs as a dietary source of each nutrient

Annex C: Analytical data

Macronutrients

Composite sample number	Sample description	Water g/100g	Protein g/100g	Total fat g/100g	Ash g/100g	Carbohydrate g/100g	Energy (kcal)/100g	Energy (kJ)/100g	Englyst fibre g/100g	AOAC fibre g/100g	Starch g/100g	Total sugars g/100g	Glucose g/100g	Fructose g/100g	Sucrose g/100g	Maltose g/100g	Lactose g/100g	Galactose g/100g	Oligosaccharides g/100g	Saturated fatty acids g/100g	*Cis*-monounsaturated fatty acids g/100g	*Cis*-n3 fatty acids g/100g	*Cis*-n6 fatty acids g/100g	*Cis*-polyunsaturated fatty acids g/100g	*Trans* fatty acids g/100g	Cholesterol milligrams/100g
1	Eggs, chicken, whole, raw	76.8	12.6	9.0	0.8	N/A	131	547	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.52	3.43	0.13	1.31	1.44	0.01	350
2	Eggs, chicken, white, raw	87.3	10.8	<0.5	0.7	N/A	43	184	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	N/A
3	Eggs, chicken, yolk, raw	48.8	16.4	31.3	1.6	N/A	347	1437	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.81	11.98	0.45	4.52	4.97	0.05	1255
4	Eggs, chicken, whole, boiled	75.4	14.1	9.6	0.9	N/A	143	595	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.70	3.67	0.14	1.38	1.51	0.01	360
5	Eggs, chicken, white, boiled	85.8	13.0	N/A	0.7	N/A	52	221	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Eggs, chicken, yolk, boiled	47.2	16.7	32.6	2.0	N/A	360	1490	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.21	12.48	0.47	4.70	5.17	0.05	1175
7	Eggs, chicken, whole, poached	75.3	13.3	10.6	0.8	N/A	149	618	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.00	4.02	0.15	1.55	1.70	0.02	423
8	Eggs, chicken, whole, fried in sunflower oil	68.0	14.7	15.7	0.9	N/A	200	831	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.35	5.38	0.14	4.06	4.21	0.02	371

Micronutrients

Composite sample number	Sample description	Vitamin A (micrograms/100g*	Vitamin D micrograms/100g	Thiamin milligrams/100g	Riboflavin milligrams/100g	Niacin milligrams/100g	Tryptophan/60 milligrams/100g	Vitamin C milligrams/100g	Vitamin E milligrams/100g	Vitamin B_6 milligrams/100g	Vitamin B_{12} micrograms/100g	Folate micrograms/100g	Pantothenic acid milligrams/100g	Biotin micrograms/100g	Sodium milligrams/100g	Potassium milligrams/100g	Calcium milligrams/100g	Magnesium milligrams/100g	Phosphorus milligrams/100g	Iron milligrams/100g	Copper milligrams/100g	Zinc milligrams/100g	Choride milligrams/100g	Iodide micrograms/100g	Manganese milligrams/100g	Selenium micrograms/100g
1	Eggs, chicken, whole, raw	126	3.15	0.08	0.50	0.05	3.4	N/A	1.29	0.13	2.70	47	1.35	19.5	154	145	46	13	179	1.72	0.05	1.12	180	50	0.03	23
2	Eggs, chicken, white, raw	N/A	N/A	0.02	0.42	0.04	2.8	N/A	N/A	0.04	0.33	10	0.28	5.6	185	149	6	12	12	0.01	0.02	0.01	159	4	<0.01	8
3	Eggs, chicken, yolk, raw	447	12.80	0.20	0.59	0.04	2.8	N/A	5.21	0.35	8.21	122	4.53	63.6	52	124	149	12	600	6.24	0.16	4.03	163	130	0.11	59
4	Eggs, chicken, whole, boiled	120	3.20	0.08	0.47	0.08	3.6	N/A	1.63	0.10	2.00	30	1.25	16.7	150	141	55	14	205	1.97	0.07	1.32	179	52	0.04	27
5	Eggs, chicken, white, boiled	N/A	N/A	0.03	0.20	0.06	4.0	N/A	N/A	0.03	0.53	4	0.22	3.2	151	123	8	12	13	0.05	0.04	0.10	164	4	<0.01	11
6	Eggs, chicken, yolk, boiled	410	12.55	0.19	0.58	0.03	3.0	N/A	4.78	0.31	7.23	101	3.72	50.0	52	119	147	12	600	6.21	0.15	3.90	180	137	0.11	64
7	Eggs, chicken, whole, poached	150	2.90	0.09	0.41	0.07	3.2	N/A	1.82	0.11	1.83	49	1.30	15.1	121	117	50	12	195	1.93	0.08	1.25	138	54	0.03	28
8	Eggs, chicken, whole, fried in sunflower oil	190	1.90	0.06	0.46	0.06	3.5	N/A	3.84	0.12	1.00	25	1.22	18.2	172	164	53	14	209	2.03	0.06	1.30	188	58	0.03	27

* Total vitamin A is calculated as retinol equivalents and is equal to retinol + (beta-carotene equivalents/6)
N/A = Not Analysed

< = Result was below the analytical limit of quantification (LOQ) or limit of detection (LOD). There is no distinction between '<' and 'not detected'

Annex D: Analytical methods used

Moisture:
A homogenised portion of the sample is mixed with sand and heated to 102°C. The moisture loss is determined gravimetrically.
Accredited to BS/EN ISO/IEC 17025:2005. UKAS 0680
Ref: BS 4401 pt3:1997
LOQ 0.1 g/100g

Ash:
A homogenised portion of the sample is ashed in a muffle furnace at 550°C. The ash is determined gravimetrically.
Accredited to BS/EN ISO/IEC 17025:2005. UKAS 0680
Ref: BS 4401 pt11:1998
LOQ 0.1 g/100g

Protein:
The sample is analysed using Leco instrumentation following the Dumas procedure: The sample is combusted in an oxygen atmosphere, the gaseous product is cleaned and nitrogen compounds converted to nitrogen which is measured by a thermal conductivity cell. The crude protein is calculated by multiplying by the appropriate conversion factor.
Accredited to BS/EN ISO/IEC 17025:2005. UKAS 0680
LOQ 0.1 g/100g

Fat:
The sample is acid hydrolysed with hydrochloric acid, cooled, filtered and dried. The fat is extract from the residue with petroleum ether and the dried fat determined gravimetrically.
Accredited to BS/EN ISO/IEC 17025:2005. UKAS 0680
Ref: BS 4401 pt4:1970 (Weibull Stoldt)
LOQ 0.1 g/100g

Fatty acids:
The lipid fractions of the sample are solvent extracted. The isolated fat is transesterified with methanolic sodium methoxide to form fatty acid methyl esters (FAMES). The FAME profile is determined using capillary gas chromatography (GC). Quantification and identification of individual FAMEs in the test material is achieved with reference to calibration standards.
Accredited to BS/EN ISO/IEC 17025:2005. UKAS 0680
LOQ 0.01 mg/100g

Sugars:
The sugars are extracted with water, clarified and chromatographically separated on an amine column with an acetonitrile/water mobile phase. The sugars are detected using an evaporative light scattering detector and quantified with reference to calibration standards.
Accredited to BS/EN ISO/IEC 17025:2005. UKAS 0680
LOQ 0.1 g/100g

Starch:
The method consists of two separate determinations. The sample is treated with warm diluted hydrochloric acid, clarified and filtered; the optical rotation of the resulting solution is determined. In the second determination, the sample is extracted with 40% ethanol and filtered. The filtrate is acidified with hydrochloric acid, clarified and filtered again; the optical rotation of the resulting solution is determined at 20 ±2ºC.
Accredited to BS/EN ISO/IEC 17025:2005. UKAS 0680
Ref: The Feeding Stuffs (Sampling and Analysis) Regulations 1982 Method 30a.
LOQ 2 g/100g

Oligosaccharides:
Malto-oligosaccharides (DP1-7) are determined individually by High Performance Anion

Exchange Chromatography with Pulsed Amperometric Detection. In-house method

LOQ 0.1 g/100g

Dietary Fibre:
AOAC
The sample is weighed and de-fatted if necessary. It is then gelatinised and treated with α-amylase and further digested enzymatically with protease and amyloglucosidase to remove the starch and protein. The dietary fibre is precipitated with IMS, filtered, washed, dried and weighed. Total dietary fibre is then determined gravimetrically and corrected for protein and ash.
Accredited to BS/EN ISO/IEC 17025:2005. UKAS 0680
Ref: AOAC 985.29/45.4.07 (2007)
LOQ 0.5 g/100g

Englyst (Non-starch polysaccharides)
Englyst Fibrezym kit with colorimetric end point
LOQ 0.2 g/100g

Cholesterol:
Method Lipid in sample is saponified at high temperature with ethanolic KOH solution. Unsaponifiable fraction containing cholesterol and other sterols is extracted with toluene. Sterols are derivatized to trimethylsilyl (TMS) ethers and then quantified by GC.
LOQ 0.7 mg/100 g
Reproducibility 20%
Reference Method ISO 6799: 1992

Inorganics:
Sodium, Potassium, Calcium, Magnesium, Copper, Iron, Manganese, Zinc, Phosphorus, Selenium
Samples are digested in acid under oxidising conditions, using sealed ‘bombs’ in automated microwave digestors, to prevent losses of volatile metals/inorganics, Metals (and some inorganics) are then determined by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) or by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). These techniques allow the sensitive and accurate (true and precise) determination of metals in foods and allow matrix interferences to be overcome.
In house methods - UKAS accredited.

Iodide
Concentrations are determined by high resolution ICP-MS after extraction with tetra methyl ammonium hydroxide.
UKAS accredited.

Chloride
Concentrations are determined using a Corning Chloride Analyser after extraction with nitric acid.
In house method FFF/B1-2104 - UKAS accredited.

Vitamins – Water Soluble:
Thiamin, Riboflavin & Vitamin B6
Thiamin, riboflavin and Vitamin B6 are determined by HPLC after appropriate and controlled acid and enzymatic hydrolysis. The methods are based on published CEN Standards. The selected method enables determination of total B6 as pyridoxine and is most appropriate to samples of this type where pyridoxine or its phosphate will form the major vitamin B6 component.
UKAS accredited.

Niacin, Total Folate, Biotin, Pantothenic acid
Determined using microbiological assay (MBA) procedures with detection carried out using VitaFast® MBA test kits.
UKAS accredited.

Tryptophan
Determined by HPLC using fluorescence detection after alkaline hydrolysis. Tryptophan contributes to the available Niacin on the basis that Niacin = Tryptophan/60.

Vitamin B12
Vitamin B12 is extracted from food by autoclaving in acetate buffer in the presence of cyanide. Vitamin B12 is determined by microbiological assay using *L.Delbrueckii.Lactis.*
UKAS accredited.

The B-vitamin results are expressed as follows:

Thiamin:	thiamin chloride hydrochloride
Riboflavin:	free riboflavin
Niacin:	nicotinic acid
Vitamin B6:	pyridoxine hydrochloride
Pantothenate:	pantothenic acid
Biotin:	d-biotin
B12:	cyanocobalamin
Total folate:	pteroyglutamic acid

Vitamin C
Vitamin C is determined by HPLC using fluorescence detection.

Oil Soluble Vitamins:

Vitamins A, D, E and the carotenoids are determined using an in house procedure involving saponification of the sample, solvent extraction and HPLC determination - UKAS accredited methods based on:

- Vitamin A – Retinol: BS EN 12823-1:2000. Foodstuffs-Determination of Vitamin A by High Performance Liquid Chromatography-Part 1: Measurement of Retinol
- Vitamin A – β-Carotene: BS EN 12823-2:2000. Foodstuffs-Determination of Vitamin A by High Performance Liquid Chromatography-Part 2: Measurement of β-Carotene
- Vitamin D: BS EN 12821:2000. Foodstuffs-Determination of Vitamin D by High Performance Liquid Chromatography-Measurement of Cholecalciferol (D3) and Ergocalciferol (D2)
- Vitamin K: Based on BS EN 14148: Determination of vitamin K1 by HPLC modified to include K2 isomers. After enzymatic removal of fat, vitamin K1 is extracted into organic solvent and is determined by HPLC with post-column reduction and fluorescence detection
- Vitamin E: BS EN 12822:2000. Foodstuffs-Determination of Vitamin E by High Performance Liquid Chromatography-Measurement of α-, β-, γ- and δ-tocopherols.

The total vitamin E figure takes into account the relative biological activities of the different isomers. Vitamin E is given as mg/100g of α - tocopherol equivalent. The activities used for these calculations are as shown below:

α - tocopherol	1.0
β - tocopherol	0.4
γ - tocopherol	0.1
δ - tocopherol	0.01

Total vitamin A is expressed as ug/100g all-trans retinol equivalent (ATRE) and is calculated as follows:

All-trans retinol + (0.75*13-cis retinol) +(β-carotene/6) +(other active carotenoids/12)

UKAS accredited.

Choline
Determined by ion-exchange HPLC with conductivity detection

Amino Acids
Determined using an automated amino acid analyser – AACC 07-01, EC Dir. 98/64, ISO 13903:2005.
LOQ 10mg/100g
RSD=2.3-6.9%

Details of the quality control measures employed are given in the analytical report associated with this project, available at www.dh.gov.uk/publications.

References

[1] Responsibility for nutrition policy in England transferred from the Food Standards Agency to the Department of Health (DH) on 1st October 2010. Management of the rolling programme of nutrient analysis has also transferred to DH

[2]Food Standards Agency. *Management of the Food Standards Agency programme of nutrient analysis and associated work* http://collections.europarchive.org/tna/20100907111047/http://food.gov.uk/science/dietarysurveys/analyticalsurveys/n10040/ (accessed 31 May 2012)

[3]Food Standards Agency. *McCance & Widdowson's The Composition of Foods integrated dataset* http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/science/dietarysurveys/dietsurveys/ (accessed 31 May 2012)

[4] Ahn DU, Kim SM and Shu H. Effect of egg size and strain and age of hens on the solids content of chicken eggs. *Poultry Science* 1997: 76: 914-919