The nutritional composition of South African eggs

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Abstract **Samples of hens' eggs produced throughout South Africa during the winter and summer of 1990 were analysed for nutrient content to obtain representative values for inclusion in food tables intended for local use. Proximate analyses and vitamin, mineral, fatty acid and amino acid determinations were carried out on all the samples. When the analysed values obtained for whole eggs, egg yolks and egg whites were compared with values listed in the Research Institute for Nutritional Diseases food tables, a number of differences were found. With regard to the inclusion of eggs in diets in general, the cholesterol content of whole eggs was found to be 23,5% lower and the total fat and saturated fatty acid contents 9% and 10% lower, respectively, than the listed values.**

The eggs were found to be rich sources of protein of animal origin, all the essential amino acids, thiamine, riboflavin, pantothenic and folic acids, vitamin B_{12}, biotin, vitamin D_3, vitamin E and phosphorus. Eggs are readily available and inexpensive and should be included in the diets of young children, adolescents, pregnant and breastfeeding women, adults, the elderly and particularly those of all ages who are undernourished.

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While eggs were probably one of the first sources of animal protein eaten by man, the intake of eggs has declined steadily in recent years. Walker *et al.*[1] record that egg consumption in the UK was 4,8 eggs per person per week in 1968, but that this figure had fallen to 2,9 by 1986. This trend is a direct result of fears associated with the cholesterol content of eggs.

The Diet Consensus Panel of South Africa[2] and the Steering Committee of the American Heart Association[3] have recommended that the intake of dietary cholesterol not exceed 300 mg/d and that eggs, which according to international[4] and South African[5] food tables contain 548 mg cholesterol/100 g, should only be eaten 2 or 3 times a week.

However, Walker *et al.*[1] reported that recent local studies of workers on egg farms who habitually consume large quantities of eggs, and international short-term experimental studies, have not been able to produce evidence that high egg consumption significantly increases the incidence of hyperlipidaemia. In view of these findings, they asked whether eggs are not perhaps being 'overblamed'; a holistic approach to nutritional recommendations should be adopted and no single food or biochemical should be singled out exclusively, as has been the case with eggs. Although high serum cholesterol levels must be controlled, the same applies to high blood pressure, and obesity, physical inactivity and smoking are all to be discouraged. Medical practitioners and dieticians should assist their patients to adopt a common-sense approach to diet and lifestyle. In the light of the findings of the present study, eggs should once more be included in a diet rich in unrefined cereals, fresh fruits and vegetables.

In addition, it is often forgotten that eggs are a very good source of a large number of nutrients. Egg protein has a high biological value; the fat in eggs is not as saturated as other animal fats and eggs are a rich source of vitamins and minerals.

In South Africa, the *Food Composition Tables* published by the Research Institute for Nutritional Diseases (RIND) of the South African Medical Research Council[5] are the main source of information on the nutritional composition of foods. Unfortunately, because of a lack of data pertaining to local foods, most of the information contained in these tables is derived from sources published in other countries such as the USA and the UK. As a step towards the goal of obtaining reliable South African data, the Egg Board commissioned the Division of Food Science and Technology of the Council for Scientific and Industrial Research (CSIR) to analyse a series of South African egg samples. The results of this study are reported here.

Materials and methods

Egg samples from different breeds of hens (Hi-line, Hisex and Amberlink) were taken from 6 different farms across the country to represent the major suppliers of eggs in South Africa. Six samples (one from each farm) were taken during the winter and 6 again in the summer

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of 1990. The ages of the hens ranged from 23 to 42 weeks for those producing winter eggs and from 49 to 68 weeks for those producing summer eggs. There were differences in the nutrient composition of the hens' feeds on the various farms. Each sample consisted of 200 eggs. Half the eggs in each sample were separated into whites and yolks. The samples were homogenised in a food mixer, subsamples were taken for each analysis and kept frozen until the time of analysis. All the analyses were done in duplicate.

Cholesterol was determined by gas chromatography after saponification of the sample;[6] the fatty acid profile was determined by capillary gas chromatography after conversion of the fatty acids to their methyl esters;[6] moisture content was determined by drying of samples under vacuum at 70°C; ashing was done at 500°C; fat content was determined by an acid hydrolysis method,[7] protein content by the Kjeldahl method, thiamine content by a fluorometric method,[8] riboflavin content by high-performance liquid chromatography (HPLC),[9] niacin, folic acid, pantothenic acid, vitamin B_6 and vitamin B_{12} levels by microbiological methods,[10] biotin content by an enzyme-linked immunosorbent assay,[11] calcium, magnesium, sodium, potassium, copper, iron, zinc and manganese levels by atomic absorption spectrometry after ashing, phosphorus content was determined on the ash by a colorimetric method;[12] levels of vitamin D_3,[13] retinol,[13] tocopherols[6] and β-carotene[14] were determined by HPLC methods; and the amino acid profile was determined (after hydrolysis of the protein) by HPLC of the phenylthiocarbamate derivatives.[15]

The carbohydrate content of the samples was not determined, because the normal practice of calculating the carbohydrate content by difference is not valid for foodstuffs, such as eggs, which are low in carbohydrates. When carbohydrates are determined by difference, the analytical and sampling errors of four separate analyses are accumulated, resulting in a relatively large error in respect of the carbohydrate content. When the carbohydrate content of a foodstuff is very low, this error can be of the same magnitude as the carbohydrate content. The energy values were determined by multiplication of the fat and protein contents of the samples with appropriate factors. The saturated, mono-unsaturated and polyunsaturated fatty acid contents of the samples were calculated by means of conversion factors described by Paul and Southgate,[16] which make provision for the fact that the total fat content of a foodstuff includes not only fatty acids but non-fatty acid components, such as sterols, phospholipids and the glycerol components of triglycerides.

The differences found between the results of summer and winter eggs were tested for significance. A one-way analysis of variance was applied by means of a statistical programme (Statgraphics, Version 4.0, Statistical Graphic Corporation, Inc., Rockville, Md, USA).

Results

The results of the proximate, vitamin, mineral and fatty acid analyses of whole eggs produced during winter and summer are shown in Table I. Also shown in Table I are the standard deviations for the values obtained for summer and winter eggs ($N = 6$) as well as the mean composition of whole eggs compared with the composition of whole raw eggs as listed in the *Food Composition Tables* of the RIND.[5] Results are expressed in grams, milligrams, micrograms, international units and kilojoules per 100 g of sample, as received.

TABLE I.
Nutrient composition of South African eggs — values for whole raw eggs (as analysed) produced in winter and summer 1990, compared with values listed for whole raw egg in the *RIND Food Composition Tables*[5] (values per 100 g egg)

	Winter		Summer			
Nutrient	Value	SD	Value	SD	Mean	RIND
Moisture (g)	74,3	1,7	75,7	2,58	75,0	74,6
Fat (g)	10,6	1,1	10,0	1,9	10,3	11,2
Protein (g)	13,1	0,5	12,1	0,4	12,6	12,1
Energy (kJ)	615		576		596	661
Cholesterol* (mg)	401	70	437	70	419	548
Thiamine* (mg)	0,09	0,01	0,16	0,04	0,13	0,09
Riboflavin* (mg)	0,42	0,03	0,37	0,02	0,40	0,30
Niacin* (mg)	0,07	0,01	0,06	0,01	0,07	0,10
Pant. acid* (mg)	1,69	0,23	1,79	0,97	1,74	1,73
Folic acid* (μg)	35	13	56	16	46	65
Vit. B_6* (μg)	33	8	52	16	43	120
Vit. B_{12} (μg)	1,7	0,6	2,1	0,6	1,9	1,5
Biotin* (μg)	21	2	23	4	22	25
Vit. D_3 (μg)	8,29	3,52	7,58	3,82	7,94	1,75
Retinol (μg)	61	18	70	35	66	156
Vit. A (IU)	203	60	233	117	218	520
Vit. E (mg)	3,28	0,85	3,29	1,91	3,29	1,60
Calcium (mg)	41	2	37	7	39	56
Magnesium (mg)	9	1	8	1	9	12
Sodium* (mg)	132	8	120	3	126	138
Potassium* (mg)	109	4	87	3	98	130
Copper (mg)	0,12	0,02	0,11	0,02	0,12	0,10
Iron* (mg)	1,71	0,54	1,92	0,43	1,82	2,10
Zinc (mg)	1,26	0,13	1,04	0,22	1,15	1,44
Manganese (mg)	0,06	0,02	0,06	0,02	0,06	–
Phosphorus (mg)	198	14	187	37	193	180
Sat. fat. (g)	3,00		3,01		3,01	3,35
Mu. fat. (g)	4,02		3,96		3,99	4,46
Pu. fat. (g)	1,51		1,18		1,35	1,45

* Significant difference between winter and summer eggs.
Pant. acid = pantothenic acid; Sat. fat. = saturated fatty acid; Mu. fat. = mono-unsaturated fatty acids; Pu. fat. = polyunsaturated fatty acids.

In Tables II and III, the nutrient composition, as described above, is shown for samples of egg yolk and egg white, respectively.

Table IV shows the percentage contribution of the nutrient content of a typical egg portion (i.e. one large, whole raw egg weighing 50 g[17]) to the recommended

TABLE II.

Nutrient composition of South African eggs — values for whole raw egg yolks (as analysed) produced in winter and summer 1990, compared with values listed for whole raw egg yolk in the *RIND Food Composition Tables*[5] (values per 100 g egg yolk)

	Winter		Summer			
Nutrient	Value	SD	Value	SD	Mean	RIND
Moisture (g)	48,4	1,1	49,7	0,6	49,1	48,8
Fat (g)	29,1	1,8	30,1	0,9	29,6	32,9
Protein (g)	16,7	0,4	16,0	0,3	16,4	16,4
Energy (kJ)	1 361		1 386		1 374	1 546
Cholesterol (mg)	1 392	65	1 083	89	1 238	1 602
Thiamine (mg)	0,24	0,03	0,34	0,07	0,29	0,25
Riboflavin (mg)	0,46	0,06	0,42	0,18	0,44	0,44
Niacin (mg)	0,05	0,01	0,02	0,01	0,04	0,10
Pant. acid (mg)	4,74	0,96	5,19	1,44	4,97	4,43
Folic acid (μg)	129	47	176	50	153	152
Vit. B_6 (μg)	147	19	167	35	157	310
Vit. B_{12} (μg)	3,9	1,1	6,4	1,2	5,2	3,8
Biotin (μg)	46	5	50	5	48	0,0
Vit. D_3 (μg)	19,0	10,9	18,4	6,5	18,7	5,0
Retinol (μg)	309	76	201	70	255	552
Vit. A (IU)	1 030	253	670	233	850	1 839
Vit. E (mg)	7,79	1,93	7,66	3,61	7,73	4,60
Calcium (mg)	103	19	106	3	105	152
Magnesium (mg)	11	2	8	1	10	15
Sodium (mg)	46	11	43	2	45	49
Potassium (mg)	91	9	71	2	81	90
Copper (mg)	0,21	0,04	0,17	0,03	0,19	0,31
Iron (mg)	4,4	1,7	5,2	0,4	4,8	5,6
Zinc (mg)	2,7	0,8	2,8	0,3	2,8	3,38
Manganese (mg)	0,13	0,03	0,14	0,04	0,14	–
Phosphorus (mg)	407	41	369	37	388	508
Sat. fat. (g)	8,14		9,08		8,61	9,89
Mu. fat. (g)	10,93		11,85		11,39	13,16
Pu. fat. (g)	4,55		3,47		4,01	4,28

Pant. acid = pantothenic acid; Sat. fat. = saturated fatty acid; Mu. fat. = mono-unsaturated fatty acids; Pu. fat. = polyunsaturated fatty acids.

TABLE III.

Nutrient composition of South African eggs — values for whole raw egg whites (as analysed) produced in winter and summer 1990, compared with values listed for whole raw egg white in the *RIND Food Composition Tables*[5] (values per 100 g egg yolk)

	Winter		Summer			
Nutrient	Value	SD	Value	SD	Mean	RIND
Moisture (g)	87,0	0,3	86,7	1,5	86,9	88,1
Fat (g)	0,1	0,1	< 0,1		< 0,1	0,0
Protein (g)	11,4	0,4	11,1	1,1	11,3	10,1
Energy (kJ)	198		189		195	204
Thiamine (mg)	0,04	0,008	0,08	0,004	0,06	0,01
Riboflavin (mg)	0,40	0,03	0,35	0,02	0,38	0,29
Niacin (mg)	0,07	0,01	0,08	0,01	0,08	0,10
Pant. acid (mg)	0,15	0,02	0,17	0,06	0,16	0,24
Folic acid (μg)	< 1,00		< 1,00		< 1,00	16
Vit. B_6 (μg)	0,72	0,13	1,53	0,34	1,13	3,00
Vit. B_{12} (μg)	0,11	0,07	0,08	0,02	0,10	0,10
Biotin (μg)	6,67	0,46	5,53	1,01	6,10	0
Calcium (mg)	3	1,3	3	0,8	3	11
Magnesium (mg)	8	2,2	6	1	7	9
Sodium (mg)	142	26	120	12	131	152
Potassium (mg)	82	24	76	14	79	137
Copper (mg)	0,06	0,02	0,4	0,004	0,05	0,05
Iron (mg)	0,12	0,07	0,13	0,03	0,13	0,0
Zinc (mg)	0,08	0,07	0,03	0,01	0,06	0,02
Manganese (mg)	0,02	0,01	0,02	0,03	0,02	–
Phosphorus (mg)	22	10	31	10	27	11

Pant. acid = pantothenic acid.

dietary allowances (RDAs), estimated safe and adequate daily dietary intakes of biotin, pantothenic acid, copper and manganese, and the estimated minimum requirements for sodium and potassium, as published by the National Academy of Sciences of America in 1989,[18] for children between the ages of 1 and 3 years and men and women aged 25 - 50 years. With regard to fat and cholesterol, the daily intakes suggested by the Diet Consensus Panel of South Africa[2] are included in Table IV. For fat, values equal to 30% of the daily energy allowances and for cholesterol a value of 300 mg, were used.

In Table V, the results of the amino acid analyses of whole egg, egg yolk and egg white, expressed in milligrams per gram of protein, are compared with the pattern of high-quality protein recommended for human consumption by the National Academy of Sciences of America.[18]

TABLE IV.
Percentage contribution to RDAs, ESADDIs and EMRs of children (1 - 3 years), and men and women (25 - 50 years) by one large, whole raw egg weighing 50 g (as analysed)

	RDAs, ESADDIs, EMRs			% contribution by 50 g whole raw egg		
		25 - 50 yrs			25 - 50 yrs	
Nutrient	1 - 3 yrs	M	F	1 - 3 yrs	M	F
Fat* (g)	44	98	75	11,8	5,3	7,1
Protein (g)	16	63	50	39,4	10,0	12,6
Energy (kJ)	5 440	12 100	9 200	5,5	2,5	3,2
Cholesterol (mg)	300	300	300	70,0	70,0	70,0
Thiamine (mg)	0,7	1,5	1,0	10,0	4,7	7,0
Riboflavin (mg)	0,8	1,7	1,3	25,0	11,8	15,4
Niacin (mg)	9,0	19,0	15,0	0,4	0,2	0,3
Pant. acid (mg)	3,0	5,5	5,5	29,0	15,8	15,8
Folic acid (μg)	50	200	180	46,0	11,5	12,8
Vit. B_6 (μg)	1 000	2 000	1 600	2,2	1,1	1,4
Vit. B_{12} (μg)	0,7	2,0	2,0	142,9	50,0	50,0
Biotin (μg)	20	65	65	55,0	16,9	16,9
Vit. D_3 (μg)	10	5	5	39,7	79,4	79,4
Vit. A (μg) RE	400	1 000	800	8,3	3,3	4,1
Vit. E (mg)	6	10	8	27,5	16,5	20,6
Calcium (mg)	80	800	800	2,5	2,5	2,5
Magnesium (mg)	80	350	280	6,3	1,4	1,8
Sodium (mg)	< 300	< 500	< 500	21,0	12,6	12,6
Potassium (mg)	1 400	2 000	2 000	3,5	2,5	2,5
Copper (mg)	0,9	2,3	2,3	6,7	2,6	2,6
Iron (mg)	10	10	15	9,1	9,1	6,0
Zinc (mg)	10	15	12	5,8	3,9	4,8
Manganese (mg)	1,3	3,5	3,5	2,3	0,9	0,9
Phosphorus (mg)	800	800	800	12,1	12,1	12,1

* Suggested daily intake.
ESSADIs = estimated safe and adequate daily dietary intakes; EMR = estimated minimum requirements; RE = retinol equivalents.

TABLE V.
Amino acid composition of South African eggs — values for raw whole egg, egg yolk and egg white (as analysed), compared with the amino acid requirement pattern published by the National Academy of Science[18] (values in mg/g protein)

				Amino acid requirement pattern	
Amino acid	Whole egg	Egg yolk	Egg white	–2 years	Adults
Asp	82	68	86	–	–*
Glu	121	104	127	–	–*
Ser	76	75	68	–	–*
Gly	33	29	34	–	–*
Thr	44	43	42	34	9
Ala	53	47	56	–	–*
His	23	23	20	19	11
Pro	40	46	35	–	–*
Arg	63	66	55	–	–*
Val	54	47	54	35	13
Phe & Tyr	87	75	86	63	19
Met & Cys	77	54	80	25	17
Ile	40	38	42	28	13
Leu	79	77	71	66	19
Trp	17	13	19	11	5
Lys	62	66	60	58	16

*No requirement specified.

Discussion

Nutrients for which there is a significant difference ($P < 0,05$, $N = 6$) between the winter and summer eggs are marked with an asterisk in Table I. This could be due to climatic differences but it is more likely to be the result of differences in the ages of the hens (the hens producing the summer eggs were consistently older than the hens producing the winter eggs).[19] Unfortunately, the effect of hen breed and feed composition on the composition of the egg samples could not be determined because the variables were confounded. It must be kept in mind that the experiment was designed to obtain the most representative composition of South African eggs and not to determine the influence of these variables on the composition of eggs.

From Table I, it can be seen that there are a number of differences between the analytical values and those listed in the RIND food tables.[5] The most important difference as regards the use of eggs and the prevention of heart disease, is the 23,5% lower cholesterol content of the analysed samples. This difference could be due to a number of variables affecting cholesterol synthesis in hens,[19] but it is more probable that recent improvements in cholesterol assay are responsible. Beyer and Jensen[20] found a reduction of 20,8% in egg yolk cholesterol levels when they compared the results of HPLC with those obtained with traditional colorimetric methods. In the present study, cholesterol was determined by gas chromatography[6] and it seems evident that this method is also able to differentiate between cholesterol and non-cholesterol chromogens as was the case in the Beyer and Jensen study.[20]

From Table I, it is clear that whole South African eggs have thiamine, riboflavin, vitamin B_{12}, vitamin D_3, vitamin E and copper contents that exceed the listed values by more than 20%. On the other hand, the analysed eggs contain more than 12% less niacin, folic acid, vitamin B_6, biotin, vitamin A, calcium, magnesium, potassium, iron and zinc than the values given in the RIND food tables. The reasons for these differences are not clear, but could be because of differences in hen feed or breed.[19] It should be noted that the eggs did not contain α-carotene, β-carotene or β-apo-8-carotenal, which indicates that these pro-vitamin A carotenoids were absent from the feed consumed by the hens. The mean fat content of the South African eggs is 9% lower than the value published in the RIND food tables.[5] This decrease in total fat content is linked to decreases of 10% and 11%, respectively, in the saturated and mono-unsaturated fatty acid contents. The lower total fat and saturated fatty acid contents are positive attributes, which make the eggs more acceptable for inclusion in most diets.

Tables II and III indicate that there are similar differences in nutrient composition when the analysed values are compared with the values listed in the RIND food tables.[5] However, the nutritive value of the analysed eggs remains high. In Table IV it is shown that one large egg can contribute 10% or more of the RDA for protein, thiamine, riboflavin, pantothenic acid, folic acid, vitamin B_{12}, biotin, vitamin D_3, vitamin E and phosphorus and 9,1% of the iron requirement of children aged 1 - 3 years. Table V illustrates that the amino acid composition of the analysed eggs exceeds the requirements of children, as well as adults, particularly with regard to those amino acids most frequently lacking in the diets of South Africans eating a maize-based diet, namely tryptophan and lysine.[21] In other words, the inclusion of one egg at an approximate cost of 25c per day would go a long way to ensure that a child is supplied with essential nutrients, such as protein of animal origin, vitamins and certain minerals.

In the case of adults, one large egg can supply more than 10% of the RDA for protein, riboflavin, pantothenic acid, folic acid, vitamin B_{12}, biotin, vitamin D_3, vitamin E and phosphorus. For the undernourished of all ages, eggs, which are readily available and inexpensive, should be seriously considered as a valuable source of nutrients despite their cholesterol content which, as this study has shown, is not as pronounced as was previously believed.

In conclusion, the present study has shown that the nutrient composition, particularly the cholesterol content, of South African eggs differs from the values listed in the RIND *Food Composition Tables*,[5] which are used to compile diets and calculate the nutrient content of composite dishes. When the nutrient values obtained are compared with RDAs and the recommended amino acid requirement pattern, it is evident that eggs are a valuable, inexpensive source of nutrients, which deserve to be included in diets of young children, adolescents, pregnant and breast-feeding women, adults, the elderly and particularly those who are undernourished.

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