Z Ernährungswiss 37: 288–293 (1998)

ORIGINAL CONTRIBUTION

S. Kaufmann
G. Wolfram
F. Delange
W.A. Rambeck

Iodine supplementation of laying hen feed: A supplementary measure to eliminate iodine deficiency in humans?

Jodierung von Futter für Legehennen: Eine ergänzende Maßnahme zur Beseitigung von Jodmangel in der Bevölkerung?

Summary Iodine deficiency still exists in many countries worldwide, to a certain degree this is also true for Germany. Food of animal origin can be a good source for iodine depending on the feed. To investigate the possible use of laying hen feed enriched with iodine, we conducted a feeding experiment with 40 laying hens receiving feed with different amounts of iodine either as KIO_3 or in the form of seaweed. Iodine concentration in eggs increased significantly depending on iodine intake after a 2 week period. Seaweed could also be used as an iodine source by the hens.

A subsequent consumption study with 24 volunteers showed that eggs enriched with iodine can increase human's iodine excretion and therefore improve human's iodine supply. This new strategy is thought to accompany salt iodization programs, not to replace them.

Zusammenfassung Die Jodversorgung ist noch immer in vielen Ländern der Welt, zum Teil auch in Deutschland, unzureichend. Um die Eignung der Jodanreicherung in Hühnereiern zur Ergänzung der Jodmangelprophylaxe zu untersuchen, führten wir Fütterungsversuche mit verschiedenen Jodzulagen an Legehühnern durch. Im Rahmen dieses Versuchs wurde außerdem die Eignung von jodreichen Meeresalgen als Jodquelle in der Hühnerfütterung untersucht. Die Nutzung von Meeresalgen zur Sicherung der Jodversorgung ist vor allem für Länder mit großen Küstengebieten interessant, in denen Meeresalgen als billige, leicht verfügbare Jodquelle zu Verfügung stehen (z.B. Malaysia, Indonesien).

Während des vierwöchigen Fütterungsversuchs mit 40 LSL-Legehühnern erhielten vier Tiergruppen KIO_3-Zulagen (0,5 – 5,0 mg/kg), zwei Gruppen bekamen jodreiche Meeresalgen (Eucheuma spinosum) (5 % bzw. 10 % im Futter). Leistungs- bzw. Qualitätsunterschiede wurden zwischen den Gruppen nicht festgestellt. Nach vierwöchiger Versuchsdauer stieg der Jodgehalt im Gesamtei in Abhängigkeit von der Jodzulage signifikant an [von 7,2 µg/Ei (ohne Jodzulage) auf 51,4 µg/Ei (+ 5,0 mg Jod/kg)]. In den Versuchsgruppen, die Meeresalgen im Futter erhielten, kam es ebenfalls zu – im Vergleich zur Rationsgruppe ohne Jodzulage – signifikant höheren Jodkonzentrationen im Ei (33,8 µg Jod/Ei).

Im Rahmen einer fünftägigen Verzehrsstudie wurden die Hühnereier aus dem oben beschriebenen Fütterungsversuch an 24 schilddrüsengesunde Probanden verabreicht (1 Ei/d). Die absolute Jodkonzentration in Spontanurinproben stieg bei den Probanden (50 % Männer, 50 % Frauen) in Abhängigkeit vom Jodgehalt der verzehrten Eier bereits am dritten Tag tendenziell an. Obwohl lediglich eine relativ einfache Verzehrsstudie durchgeführt werden konnte, geben die Ergebnisse dennoch erste Hinweise auf den positiven Einfluß, den der Verzehr jodangereicherter Hühnereier auf die Jodversorgung ausüben kann.

Key words Iodine deficiency – eggs – algae – feed

Schlüsselwörter Jodmangel – Eier – Algen – Futter

Received: 22 December 1997
Accepted: 27 April 1998

S. Kaufmann, Prof. Dr. W.A. Rambeck (✉)
Institut für Physiologie,
Physiologische Chemie und Tierernährung
Veterinärstr. 13
D-80539 München

G. Wolfram
Institut für Ernährungswissenschaft
TU München-Weihenstephan
D-85350 Freising

F. Delange
International Council for Control of Iodine Deficiency Disorders
Avenue de la Fauconnerie 153
B-1170 Brussels,
Belgium

Introduction

Iodine deficiency is one of the four most severe types of malnutrition worldwide (in addition to protein-energy malnutrition, nutritional anemia and vitamin A deficiency). It causes not only endemic goiter (with corresponding complications and economic costs) but also mental and/or physical retardation (including cretinism) when occurring during pre- or neonatal life (3). There is some evidence that iodine deficiency during childhood and adolescence can still affect intellectual development adversely (4).

In Germany the daily iodine intake is insufficient as a consequence of low iodine concentrations in soil and drinking water. As a result goiter is still endemic in Germany in all age groups. This finding is confirmed by many studies published recently (5, 9, 12, 20). The annual costs for diagnosis and therapy of iodine deficiency goiter in Germany are estimated at 2 billion DM. In general, the most appropriate way to supplement people with iodine is the use of iodized salt in households and food industry. In Germany, the use of iodized salt has been facilitated and promoted since 1989. Therefore, the iodine intake from this source has increased (13) but still seems to be insufficient to eliminate iodine deficiency in Germany entirely (7). Additional measures seem to be necessary to complete iodine deficiency prophylaxis and reach the goal – set by the WHO – to eliminate iodine deficiency disorders (IDD) by the year 2000.

In Southeast Asia even more severe consequences of iodine deficiency exist. Besides areas with mild or moderate iodine deficiency (goiter prevalences up to 70 %, but no cretinism) (15, 18, 21) there are villages in Malaysia and Indonesia where cretinism still occurs (6, 11). Restricted reachability of these areas and eating habits based on strong traditions and therefore difficult to change require a wide range of different tools to overcome iodine deficiency.

In countries such as Great Britain and the former GDR it is known that food of animal origin (milk, eggs, and meat) could be a main iodine source for humans depending on the iodine content in feed (1, 12, 19). Studies done so far concentrated mainly on the iodine enrichment in milk and meat (19). Since eggs are a widespread foodstuff, we wanted to investigate their suitability for iodine supplementation. In addition to the carry-over of iodine into eggs, animal production and egg quality were of special interest.

Another aspect of the present work was to prove the benefit of iodine-rich seaweed as iodine source for laying hens. It is known that seaweed can be used as a cheap and in several countries easy available feedstuff for chicken and pigs (14). Currently, there is no controlled data about the consequences of seaweed as an iodine supplement in this product.

Materials and methods

Feeding experiment

Forty laying hens (LSL hens, 24 weeks old) were fed diets containing different amounts of iodine either in form of KIO_3 or as seaweed for a period of 4 weeks.

Four groups of 6 animals received iodine supplementations at the rate of 0.5, 1.0, 2.0, and 5.0 mg iodine/kg feed (as KIO_3). Two groups of 6 animals received feed supplemented with 5 or 10 % dried seaweed (Eucheuma spinosum from Nusa Penida, Indonesia) (corresponding with 2.5 or 4.9 mg iodine/kg feed). Four animals acted as the control group (without any iodine supplementation).

Eggs for iodine analysis were collected at the beginning, after 2 and 4 weeks. Egg yolks and egg whites were weighed and frozen separately (-20 °C). Weight development was noted at the same days. Feed intake was determined weekly. Egg yield was observed during the whole run of the experiment. After 4 weeks the hens were slaughtered and the right pectoral muscle (M. pectoralis) was collected for iodine analysis.

Consumption study

We conducted a human consumption study with hen's eggs from the experiment mentioned above to get first hints to the iodine carry over from eggs to humans.

Twenty-four volunteers were divided into 4 groups. Each group was attached to a laying hen group. At the beginning of the study the participants received 5 eggs from the corresponding animal group (Table 1). The participants were asked to eat one boiled egg per day in addition to their normal diet for a period of 5 days (Monday – Friday).

To judge the iodine status morning urine samples were collected before the consumption of the first egg, after 3 and 5 days, and 3 days after the last egg was eaten.

Iodine determination

Iodine concentrations in feed, eggs, and muscle were determined using the Sandell-Kolthoff-reaction after dry alkaline ashing (8). Seaweed was mineralized by the same procedure and diluted before analysis with hydrous ashing solution (blank standard).

Statistical analysis

Data were analyzed with the help of the statistic program SPSS 6.1 for Windows. The results are presented as means and standard derivation. Differences between the groups were calculated using the one-way analysis of variance. When differences between the groups were found ($p < 0.05$), significant different group means were determined by the aid of the Bonferroni-test.

Table 1 Consumption study – study design

	study group			
	I (n=6)	III (n=6)	IV (n=6)	V (n=6)
laying hen's feed supplementation	without iodine supplementation	+ 2.0 mg I/kg feed	+ 5.0 mg I/kg feed	100 g seaweed[1]/kg feed
egg's iodine content (µg/egg)	7.2±1.2	29.0±4.8	51.4±6.2	33.8±2.8

[1]Eucheuma spinosum

Results and discussion

Iodine content in eggs

Mean iodine concentrations at the beginning of our experiment were 113.5±20.5 µg/100 g in egg yolk and 4.9±1.4 µg/100 g in egg white.

Supplementation rates of 1.0 mg iodine/kg or more and seaweed addition lead to significantly increased iodine concentrations in both egg yolk and egg white after 2 and 4 weeks (Figs. 1 and 2). During the run of the experiment, the egg's iodine concentration decreased in animals that did not receive any iodine supplementation, because iodine intake was reduced compared to the period before the study began (feed supplemented with 0.58 mg I/kg feed). A supplementation rate of 0.5 mg iodine/kg did not cause any changes in egg's iodine concentrations, since iodine intake did not change compared to the period before the study began.

Total iodine content per egg was 16.1±2.7 µg at the beginning of the experiment. Increased iodine concentrations in egg white and egg yolk after iodine supplementation lead to higher iodine contents in the total egg (up to 51.4±6.2 µg iodine after supplementation of 5.0 mg iodine/kg feed). Since the actual German and European feeding law allows a maximum total iodine concentration in feed of 10 mg/kg, there remains enough space to increase iodine in feed and consequently in eggs in a very controlled way.

Iodine intake in form of KIO_3 and iodine concentrations in egg yolk or egg white correlated very well (egg yolk: $R^2=0.9322$; $p < 0.001$/ egg white: $R^2=0.7980$; $p < 0.001$). Consequently there was also a high correlation between iodine supplementation and total iodine content per egg ($R^2=0.9153$; $p < 0.001$).

Iodine concentration in pectoral muscle

Mean iodine concentration in pectoral muscle was 46.8±16.2 µg/kg in all groups that received any form of iodine supplementation. There was not any influence of the iodine supplementation rate in these groups. Since

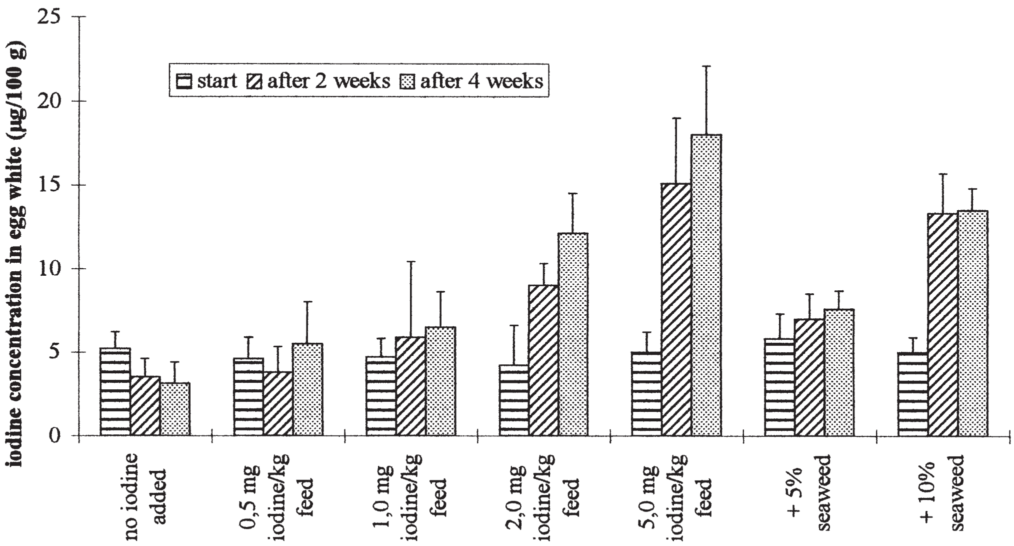
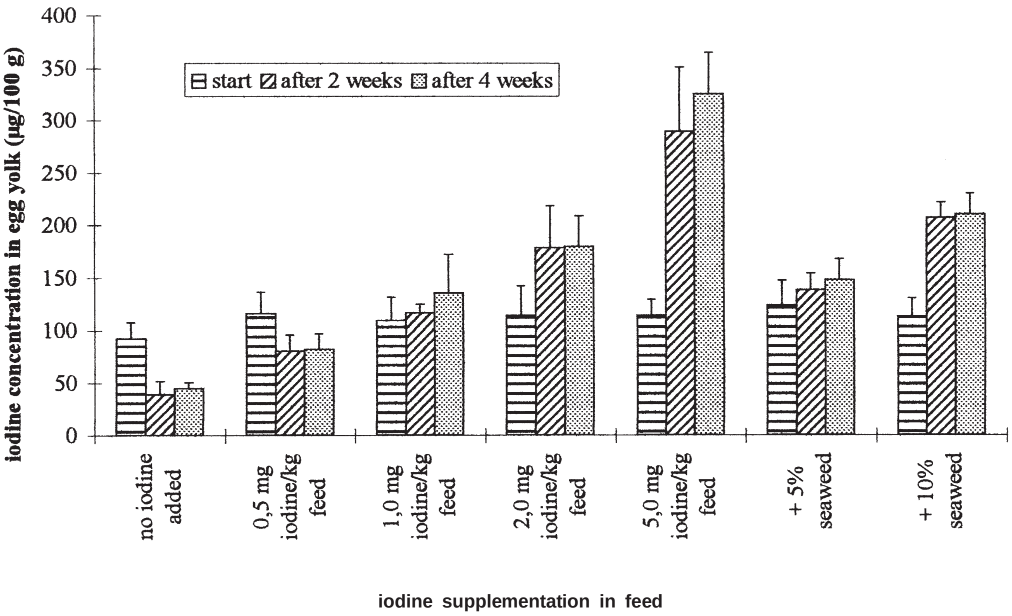


Fig. 1 Iodine concentration in egg white (µg/100 g) following iodine supplementation in feed at start and after 2 and 4 weeks.

Fig. 2 Iodine concentration in egg yolk (µg/100 g) following iodine supplementation in feed at start and after 2 and 4 weeks.



iodine is not concentrated actively in muscle (in contrast to eggs and milk) (2, 10) the experiment did not last long enough to get different iodine concentrations in the pectoral muscle of adult laying hens depending on the iodine intake. By contrast, mean iodine concentration in the pectoral muscle was 19.6±7.6 µg/kg in the group that did not receive any iodine supplementation.

Animal performance

Mean feed conversion rate was 1.95±0.23 (feed intake per produced egg mass) independent of iodine supplementation. Supplementation rates in the order of 0-5 mg iodine/kg feed both in form of KIO_3 and as seaweed did not influence the feed conversion rate.

Mean egg yields were in all ration groups very high ($\bar{x}$=98.3±4.6). Although there were not any significant differences between the groups there was a tendency for highest egg yields in the group that received a supplementation rate of 1.0 mg iodine/kg feed and constantly decreasing egg yields both in groups that received less iodine and in groups that received more iodine.

Suitability of seaweed as iodine source for laying hens

Though the bioavailibility of iodine from Eucheuma spinosum is less compared to KIO_3 (approximately 50-60 %), feeding seaweed (Eucheuma spinosum) increased iodine concentrations in egg yolk and egg white significantly. Seaweed contents of up to 10 % did not affect feed conversion rates or egg yield adversely. Reported incompatibilities of seaweed containing feed could be explained by high NaCl concentrations in most cases (14). This adverse effect was avoided by washing the seaweed fraction carefully before drying. A constant iodine content in the algae has to be guaranteed and controlled by analysis.

Renal iodine excretion after the consumption of eggs with different iodine contents

Mean renal iodine excretion was 177.0±45.5 µg/d at the beginning of our study indicating a sufficient iodine supply among the study participants. This is in contrast to results from earlier studies which found iodine deficiency in many German regions. It might be that the participants were sensitized regarding iodine supply since they were recruited from the Institute for Physiology, Physiological Chemistry, and Biochemistry and had been confronted with this problem several times in the past.

Renal iodine excretion increased after the consumption of eggs depending on their mean iodine contents (7.2 µg/egg, 29.0 µg/egg, 51.4 µg/egg, and 33.8 µg/egg) (Fig. 3). Three days after the study was completed mean iodine concentration in urine decreased below the starting values. Differences between the study groups were not significant at any moment since other influences on iodine excretion (like daily food consumption) were not controlled. Nevertheless, our results give a good indication that iodine enriched egg's could increase iodine intake and therefore improve human's iodine supply. Although, of course one can not recommend the consumption of more eggs to improve iodine uptake, this strategy could be another contribution to increase the basic supply of iodine evenly. This approach to erase IDD worldwide is thought to accompany salt iodization programs – not to replace them.

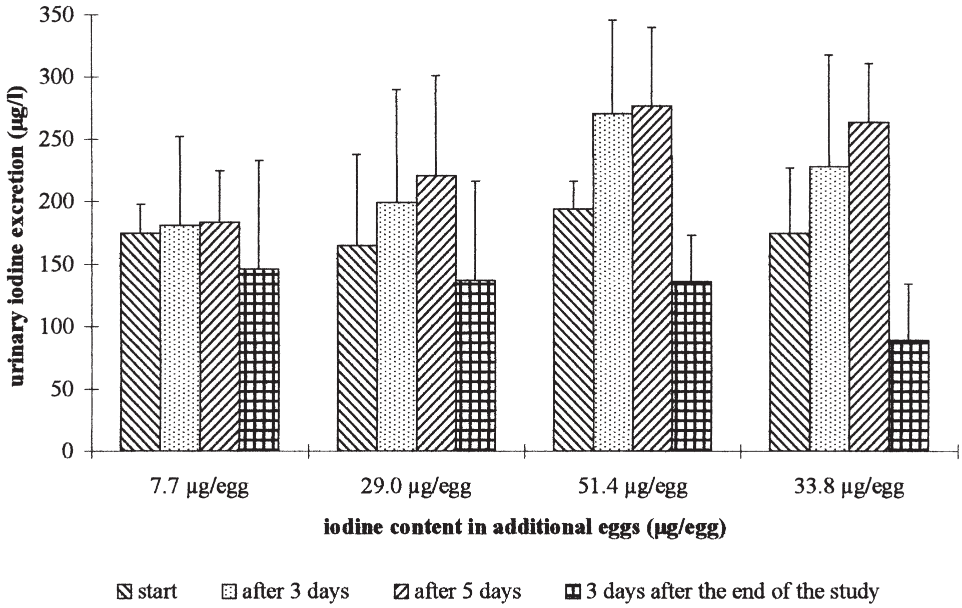


Fig. 3 Iodine concentration in urine (µg/l) before, during, and after the consumption of hen's eggs (1 egg/day from day 1 to day 5) with different iodine contents.

Conclusions

The carry-over "feed – laying hen – egg" can be used to enrich human's diet with iodine. Eggs are a suitable food of animal origin that can be enriched with iodine in a controlled way. Especially in countries with large coastal areas like Southeast Asia, the inexpensive algae can be added to the feed and, thus, present an innovative source for this essential trace element.

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