Plant Archives Vol. 18 No. 2, 2018 pp. 2485-2490 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EFFECT OF USING OF DIFFERENT LEVELS RAW RED SORGHUM TREATED AND NON-ENZYMATIC ON PRODUCTIVE CHARACTERISTICS FOR LAYING HENS

T. O. Al-Ani and Hisham A. Al-Mashhadani*

Department of Animal Production, College of Agriculture, University of Baghdad, Iraq.

Abstract

This experiment was conducted in the poultry field of the College of Agriculture, University of Baghdad in Abu Ghraib for the period from 5/11/2017 to 11/2/2018 to investigate the effect of the use of different levels of raw red sorghum treated and non-enzymatically treated (0, 10, 20, 30%) for four treatments and repeated the same ratio of four other treatments with the addition of the enzyme to the diet in the productive performance of laying. 128 hens commercial strain (Lohmman Brown) 29 week old were used in this experiment .The bireds were fed on a preliminary meal for three week, randomly distributed on eight transplants Replicate the first T1 control treatment (without red sorghum), T2 (10%) raw red sorghum, 3 T3 (20%) raw red sorghum, 4 T4 (30%) raw red sorghum, 5 treatment T5 control (without red sorghum + enzyme), treatment of the seventh T7 (20% red sorghum + enzyme), Treatment Eight T8 (30% red sorghum + enzyme). The results of the study indicated that there were no significant differences between the treatments in the attributes feed conversion ratio, weight gain and egg weight (but the study indicated a significant difference in the rate of egg production between treatment where it was delayed Treated T3. The study also showed a significant difference in feed consumption rate, where T2 treatment was the least significant in feed consumption while all parameters were similar to the egg mass, except for the T3 treatment, which was the least significant in this status from the other treatments.

Key words : Red corn, white chicken, productive qualities.

Introduction

The cost of feeding poultry and processing the bulk of the costs involved in the production process, which may reach 70-75% (Sharif, 2012). Therefore, it is imperative for nutritionists to look for available alternatives that can replace major sources such as yellow sorghum and wheat to achieve the same goal (Ojewola, 2006). Red sorghum is one of the feed alternatives that can be used for this purpose because it contains (10.9%) protein, metabolism energy (3290 kcal/kg), (Serna-Saldivar, 1991). The red sorghum is characterized by its resistance to hot and dry conditions. It is suitable for agriculture in the semi-arid and low rainfall regions. It is characterized by its tolerance to salted soils and saline wellwater. It can produce abundant crops in climatic conditions where other crops .contain red sorghum seeds on some anti-nutrients such as phytic acid and tannin. Therefore, the use of red sorghum at high levels requires treatments to reduce the negative effect of tannin, which is linked to protein and other nutrients and make them unavailable for absorption, same of these treatments represented by the use of enzymes and chemical treatment as well as deformation and fermentation and germination (Musharaf, 1991; Hamid, 2001; Talha, 2008; Torki, 2007; Sharif, 2012), which reduces the effect of tannin to zero (Albin, 1975). The low cost of enzymes encouraged their use in the feed for their effect on feed materials and made them more ready to benefit birds, which reflected positively on the productive performance of birds (Choct, 1992; Murphy, 2005). The aim of this study is to investigate the effect of using different levels of raw sorghum treated and non-enzymatically treated on the productive performance of the laying hens and to determine the optimal level.

***Author for correspondence :** E-mail: hishamasm79@yahoo.com

Table 1 : Chemical analysis of red sorghum.

Sequence	Material	Value
1	Ash-as	1.4937 %
2	Fat-as	2.3763 %
3	Fibre-as	4.7246 %
4	Moisture	10.971 %
5	Protein-as	10.258 %
6	Starch-as	48.348 %
7	Tannin-as	1.3223 %
8	Methionine	2.19%
9	Lycin	0.117%
10	Cystin	0.532%
11	Energy Metabolism	2871.9 (kcal/kg)
12	Calcium	0.038
13	Phosphor	0.3

completed, were the chicken housed (40 × 40 × 40) in an 8 × 4-room hall, ventilated with air-pull fans, 14-hour daylight lighting and free water. The feed was weighed daily at 120 g/Bird and the remaining weight every 14 days to know the amount of feed consumed in addition to the weight of chickens in the same period to know the chicken and the feeding of the chicken (food was content of deferent ratio of red sorghum showed in picture 1 and its Chemical Analysis showed in table 1 as shown in table 2. The eggs are collected twice a day and the calculation of the qualities of productivity and quality every 14 days during the trial period of 14 days and carried out the experiment according to a general study.

Results and Discussion

The results of the study (tables 4-7-8) showed that there were no significant differences between the treatment for the properties (egg weight, food conversion coefficient and weight increase rate) during the 14-week trial period. However, the results of the general average (table 4) showed that T3 was significantly lower than the rest of the T1-T2-T4-T5-T6-T7-T8 in the average of egg production. Table 5 indicated the similarity in all treatment

Table 2 : Percentages and calculated chemical composition of the relational components used in the study.

Usage ratios(%) / Feeding materials	Control	10% red sorghum	20% red sorghum	30% red sorghum
Yellow corn	34	31.3	30.3	26.8
Red sorghum	0	10	20	30
Wheat	33.4	26	16	9
Soybean Meal	18.5	18.5	19	19
Center protein 1	5	5	5	5
Limestone	7.7	7.7	7.7	7.7
D/Calcium phosphate	0.5	0.5	0.5	0.5
Vegetable oil	0.5	0.6	1.1	1.6
A mixture of vitamins and minerals	0.2	0.2	0.2	0.2
Salt	0.2	0.2	0.2	0.2
Total	100	100	100	100
Calculated chemical analysis 2				
Crude protein %	17.6	17.55	17.58	17.51
Metabolism Energy (kcol/kg)	2783.73	2758.59	2757.98	2754.02
Methionine %	0.38	0.38	0.38	0.38
Lysine %	0.9	0.9	0.9	0.9
Cestin %	0.3	0.3	0.3	0.9
Calcium %	3.35	3.35	3.35	3.35
Phosphorus available %	0.35	0.35	0.35	0.35

1: Waffi protein center Origin: Energy 2125 kcal / kg, 40% crude protein, calcium 5%, phosphorus available 3.85%, methionine 2.85%, lysine 3.8%, methionine methionine 3.29%.

2: The values of the chemical composition of feedstuffs were calculated according to NRC (1994).

Materials and Methods

This experiment was conducted in the poultry field of the Department of Animal Production at the College of Agriculture University of Baghdad for the period from 5/11/2017 to 11/2/2018. It was used in the experiment 128 chickens of the Lohmman Brown were age of 19 weeks, and all the required vaccinations has been

Table 3 : Effect of using different levels of raw red sorghum treated and non-enzymatic ally treated in laying hens diets on egg production rate±Standard error during production period (25-25) weeks of age.

Duration /day Treat-ment	23-22	25-24	27-26	29-28	31-30	33-32	35-34	General Average 35-22
T1	85.27±5.01	91.51±1.33	97.32 ±0.51a	96.42±0ab	96.42±0.72	95.98± 0.44a	97.32± 0.51a	94.32±1.00a
T2	83.93±5.59	97.76±0.44	96.42±1.26a	97.32±0.51a	96.87±0.44	95.98 ±0.44a	96.42±0a	94.96± 0.63a
T3	65.63±5.12	89.28 ±2.62	84.82±5.18b	88.39 ±1.15b	91.07±3.34	91.07±4.63a	91.95± 3.67	86.03±1.25b
T4	86.16±6.20	92.41±3.81	94.64 ±2.18a	88.39 ±3.04b	91.07±6.01	89.73±5.56a	91.96±5.12ab	90.62±2.98a
T5	87.50±3.41	96.87±2.10	95.98 ±0.85a	95.53 ±2.77ab	92.85±2.82	96.87± 2.90a	96.42±3.52a	94.57±0.51a
T6	77.23±5.93	99.10± 0.89	95.53± 1.85a	94.64 ±4.18ab	95.98±3.44	95.08±1.33a	92.85±4.18ab	92.92±1.28a
T7	66.07±14.45	84.82 ±12.80	95.98 ±2.34a	93.30±3.20ab	95.53±0.89	96.42±1.45a	94.19± 1.33ab	89.47±4.318ab
T8	66.07 ±10.92	98.21±1.03	94.64±1.03a	95.08±2.56ab	97.32±1.54	97.32±0.51a	92.85±1.92ab	91.64±1.23a
Morality	N.S	N.S	**	**	N.S	N.S		N.S **

T1 (control free of red corn), T2 (red corn kernel 10%), T3 (20% red corn), T4 (30% red corn)T5 (control control free of red corn + enzyme),T6 (red corn kernel 10% + enzyme), T7 (red corn kernel 20% + enzyme), T8 (red corn kernel 30% + enzyme)

** The averages with vertically different letters indicate significant differences between the mean of the coefficients at (P <0.05)

N.S indicate that there are no significant differences between the averages of transactions.

Table 4 : Effect of using different levels of raw red sorghum treated and non-enzymatically treated in laying hens diets on average egg weight ± Standard error during production period (35-22) weeks of age.

Duration /day Treat-ment	23-22	25-24	27-26	29-28	31-30	33-32	35-34	General Average 35-22
T1	53.98±0.90	55.64±a b 1.09	58.09±cb 1.31	60.32±bc 0.59	58.85±2.61	61.26± 1.30	62.75± 0.97	58.70 ± 0.72
T2	54.08±0.79	55.21± 0.70ab	58.08±cb 0.39	60.35±0.76bc	60.29±2.53	60.92±2.51	68.41±5.15	59.62± 0.87
T3	51.68±1.14	54.28±1.13 b	59.30±cb 1.05	60.53±2.44bc	61.05±1.10	64.18±4.12	65.65± 2.65	59.52± 1.37
T4	52.71±1.43	55.75±2.15ab	59.76±0.84abc	61.35±1.90abc	59.52±1.79	62.35±2.73	68.12±2.09	59.94±1.37
T5	53.79±1.16	55.49±ab 1.38	58.91±0.51cb	61.74±1.99abc	65.91±1.79	58.74± 2.90	61.80±3.52	59.48 ± 1.51
T6	56.18±1.67	58.41±a 0.63	62.54±a 1.11	65.50±a 1.12	62.22±2.82	64.05±1.05	66.71±1.33	62.23 ±0.96
T7	54.24±1.45	55.18±1.22 ab	57.00±1.05 c	58.12± c 1.31	65.67±3.94	60.88±2.56	63.59± 1.70	59.24±0.74
T8	52.95±3.86	56.85±ab 0.44	60.49± ab 0.52	63.36±ab 0.90	60.61±2.88	57.47±2.78	65.78±2.87	59.64 ±1.33
Morality	N.S	**	**	**	N.S	N.S	N.S	N.S

· T1 (control free of red corn), T2 (red corn kernel 10%), T3 (20% red corn), T4 (30% red corn)T5 (control control free of red corn + enzyme),T6 (red corn kernel 10% + enzyme), T7 (red corn kernel 20% + enzyme), T8 (red corn kernel 30% + enzyme)

· ** The averages with vertically different letters indicate significant differences between the mean of the coefficients at (P <0.05)

N.S indicate that there are no significant differences between the averages of transactions

Table 5 : Effect of using different levels of raw red sorghum treated and non-enzymatically treated in laying hens diets on egg mass rate ± Standard error during productive period (25-25) weeks of age.

Duration / Treat-ment	23-22	25-24	27-26	29-28	31-30	33-32	35-34	General Average 35-22
T1	46.02±2.29	50.92 ± ab 1.26	56.53 ±1.43a	58.16 ± 0.57ab	56.75±2.88	58.80± 1.41	61.07± 0.91	55.36 ±0.95ab
T2	45.39±3.06	53.97 ± 0.74ab	56.01 ± 0.99a	58.73 ± 0.74ab	58.40±2.71	58.50 ±2.64	65.96± 4.97	56.61 ±0.80a
T3	33.92±3.32	48.46±2.46ab	50.30±3.27a	53.50±2.62b	55.59±1.88	58.44±1.17	60.36± 2.54	50.10±1.66b
T4	45.41±4.08	51.52± 3.30ab	56.57±1.78a	54.23±2.66b	54.20±4.06	55.94±3.44	62.64±5.07	54.32 ±2.56ab
T5	47.06± 1.74	53.75± ab 0.70	56.54±0.17a	59.00±3.09ab	61.19±0.66	56.90± 2.95	59.58±3.22	56.25±1.64a
T6	43.38±3.99	57.88±a 0.91	59.74±0.85a	61.99±2.53a	59.72±3.76	60.89±0.61	61.94±2.59	57.82±1.12a
T7	35.84±7.80	46.80±7.43 b	54.70±1.31ab	54.23±2.97b	62.73±3.13	58.70±2.41	59.89± 1.41	53.00±2.72ab
T8	34.98±7.52	55.83 ± ab 0.57	57.24 ±0.21a	60.24±1.12ab	59.00±3.26	55.92±2.51	61.07±2.18	54.65±1.31ab
Morality	N.S	**	**	**	N.S	N.S	N.S	**

T1 (control free of red corn), T2 (red corn kernel 10%), T3 (20% red corn), T4 (30% red corn)T5 (control control free of red corn + enzyme),T6 (red corn kernel 10% + enzyme), T7 (red corn kernel 20% + enzyme), T8 (red corn kernel 30% + enzyme)

** The averages with vertically different letters indicate significant differences between the mean of the coefficients at (P <0.05)

N.S indicate that there are no significant differences between the averages of transactions.

Table 6 : Effect of the use of different levels of raw red sorghum treated and non-enzymatically treated in laying hens diets on average consumption.

Duration / Treat-ment	23-22	25-24	27-26	29-28	31-30	33-32	35-34	General Average 35-22
T1	5.21 ± 98.89	3.48 ± 109.00	115.00 ± 0.00a	177.90± 1.05ab	117.06±1.10a	119.42±a 0.34a	119.95± 0.05a	113.88±8.03ab
T2	3.38 ± 98.20	2.34 ± 108.79	111.29± 1.70b	111.92 ± 1.83b	111.0± 1.58b	112.08 ±1.45b	119.48± 3.47b	110.39± 8.34b
T3	5.12 ± 97.5	3.11 ± 107.54	113.30± 1.11ab	2.53± 114.40ab	112.82± 1.99ab	116.90± 2.12a	117.23 ± 1.94ab	111.38 ± 14.26ab
T4	2.40 ± 101.35	1.83± 109.58	112.34 ± 1.49ab	117.19 ± 1.53ab	114.39 ± 2.45ab	118.85 ± 0.67a	119.60 ± 0.30a	113.32± 9.39ab
T5	2.52 ± 102.37	1.06± 113.06	114.84 ±0.09ab	118.53± 0.11a	115.88 ± 0.91ab	118.72 ± 0.65a	118.42 ± 1.58ab	114.52 ± 5.18a
T6	4.77 ± 96.42	3.03 ± 107.61	112.19 ±1.46ab	114.53± 3.25ab	116.34 ± 1.95ab	118.41 ± 0.89a	119.62 ± 0.23a	112.16 ± 11.56ab
T7	2.96 ± 103.19	2.15± 111.33	114.26 ±0.74ab	118.79 ± 0.80a	117.58 ± 1.42a	119.80 ± 0.12a	119.87 ± 0.13a	114.17 ± 7.26a
T8	3.59± 99.00	2.12± 111.79	114.33 ±0.56ab	116.70 ± 2.62ab	115.66 ± 1.66ab	119.69± 0.31a	119.54 ± 0.32a	113.81 ± 10.34ab
Morality	N.S	N.S.	**	**	**	**	**	**

T1 (control free of red corn), T2 (red corn kernel 10%), T3 (20% red corn), T4 (30% red corn)T5 (control control free of red corn + enzyme),T6 (red corn kernel 10% + enzyme), T7 (red corn kernel 20% + enzyme), T8 (red corn kernel 30% + enzyme)

** The averages with vertically different letters indicate significant differences between the mean of the coefficients at (P <0.05)

N.S indicate that there are no significant differences between the averages of transactions

Table 7 : Effect of the use of different levels of raw red sorghum treated and non-enzymatically treated in laying hens in conversion rate.

Treat-ment / Duration /day	23-22	25-24	27-26	29-28	31-30	33-32	35-34	General Average 35-22
T1	0.46 ± 2.14b	0.09±2.14	2.03 ± 0.04	0.02 ± 2.02	0.06 ± 2.06	0.04 ± 2.03	0.03 ± 1.96	0.05 ± 2.05
T2	0.35 ± 2.16b	0.08 ± 2.01	0.17 ± 1.98	1.90 ± 0.09	0.04 ± 1.90	1.92± 0.15	0.10 ± 1.81	0.12 ± 1.95
T3	0.09 ± 2.87b	0.17 ± 2.21	0.08± 2.25	0.16 ± 2.13	0.16 ± 2.02	0.13 ± 2.00	1.94± 0.16	2.17± 0.11
T4	0.20 ± 2.23b	2.20± 0.10	2.03 ± 0.04	2.16 ± 0.11	2.11± 0.08	2.12 ± 0.07	1.90± 0.09	2.08± 0.07
T5	0.08 ± 2.17b	2.10± 0.05	2.03 ± 0.03	2.00 ± 0.04	1.89 ± 0.04	2.08 ± 0.04	1.98± 0.04	2.03 ± 0.02
T6	1.06 ± 2.22a	1.86 ± 0.51	1.88 ± 0.05	1.84 ± 0.17	1.94 ± 0.05	1.94± 0.02	1.93 ± 0.02	1.94 ± 0.11
T7	0.27± 2.87b	2.37 ± 0.05	2.08± 0.02	2.19 ± 0.06	1.87 ± 0.06	2.04 ± 0.02	2.00 ± 0.05	2.16± 0.04
T8	0.22 ± 2.87b	2.00 ± 0.02	2.00 ± 0.05	1.93 ± 0.07	1.96 ± 0.06	2.14 ± 0.02	1.96± 0.07	2.08 ± 0.05
Morality	N.S	N.S	N.S	N.S	N.S.	N.S.	N.S.	N.S.

T1 (control free of red corn), T2 (red corn kernel 10%), T3 (20% red corn), T4 (30% red corn)T5 (control control free of red corn + enzyme), T6 (red corn kernel 10% + enzyme), T7 (red corn kernel 20% + enzyme), T8 (red corn kernel 30% + enzyme)

** The averages with vertically different letters indicate significant differences between the mean of the coefficients at ($P < 0.05$)

N.S indicate that there are no significant differences between the averages of transactions

Picture 1 : Red sorghum.

in the value of egg mase except T3. Also, the results of table 6 showed that there were significant differences in feed consumption between T1-T3-T4-T5-T6-T7-T8, which are significantly higher than T2.

From the results of the tables for the production performance of laying hens (egg production, egg weight, egg mass and food conversion coefficient) showed no significant differences between these parameters. Among the birds fed on diets that contain are different percentages of raw red sorghum (10- 20-30%) and non-red sorghum-treated birds. This is a positive result since it has no negative effects on the performance of birds. This may be due to the nutritional value of this new feed material and its relative nutrient content of sorghum Protein and amino acids. In addition, it may be a digestion factor and facilitate of these nutrients is high, which reflected on the conversion or representation of these elements and the usage of them significantly. The evidence on that there was no effect on the productive performance of birds.

Albin (1975) and Selle (2016) pointed out that the process of grind the red sorghum and peeling it positively effect on its nutritional value by reducing the level of tannin and increasing the digestion factor and the absorption of nutrients in it. In addition to the role of the enzymes that have been added to the diete of treatment T6-T7-T8. These enzymes work on breaking down the inhibitory factors that may be present in the red sorghum, whose presence affects natural digestion. These enzymes also release some associated elements, which increase the digestibility factor and benefit from proteins and carbohydrates as well as minerals, which in turn positively affect the performance of birds (Sheppy, 2003; Pariza, 2010).

Conclusion

The results indicate that the red sorghum can be used

Table 8 : Effect of using different levels of raw red sorghum treated and non-enzymatically treated in laying hens diets on the rate of changes in body weight ± Standard error during productive period (25-25) weeks of age.

Duration /day Treat-ment*	23-22	25-24	27-26	29-28	31-30	33-32	General Average 33-22
T1	-46.00 ± 52.22	26.70±84.38	106.25±10.781[a]	11.78± 3.13	6.89±46.88	19.56±25.63	65.57±220.25
T2	48.80±116.69	11.70±54.06	16.01 ±98.44a	28.44± 25.11	20.13±33.44	42.50± 9.93	56.14±373.56
T3	44.59±-19.44	19.00±30.94	15.94 ± 95.94a	4.87±54.68	15.85±39.69	21.73±31.56	233.38± 33.19
T4	77.04±109.69	63.75± 7.19	14.69 ± 12.02 cd	70.00± 17.37	11.56± 17.37	53.75± 16.47	323.44± 51.19
T5	74.31±139.50	71.25± 20.57	74.68±14.28 ab	34.69± 13.70	15.63± 9.87	25.00± 27.59	360.75± 80.99
T6	78.20±-5.69	82.50± 38.39	61.88±17.65abc	70.00± 37.07	23.13± 11.09	33.88± 8.33	265.69± 61.29
T7	63.34±-4.25	84.69± 12.06	29.06± 30.94bcd	65.31± 15.23	16.25± 11.31	29.69± 8.13	220.75± 78.46
T8	97.88±-8.19	81.88± 28.30	5.63 ± 11.78d	70.00± 20.31	-54.06± 82.44	70.00± 81.05	165.25± 83.04
Morality	N.S	N.S	**	N.S	N.S	N.S	N.S

T1 (control free of red corn), T2 (red corn kernel 10%), T3 (20% red corn), T4 (30% red corn)T5 (control control free of red corn + enzyme),T6 (red corn kernel 10% + enzyme), T7 (red corn kernel 20% + enzyme), T8 (red corn kernel 30% + enzyme).
** The averages with vertically different letters indicate significant differences between the mean of the coefficients at ($P < 0.05$)
N.S indicate that there are no significant differences between the averages of transactions

in the diet of laying hens at the level of 30% either as carde or enzymatic treated as it did not show any negative effect on the productive characteristics for laying hens.

References

Albin, C. A. and D. Heitz (1975). Nutritional characteristics of sorghum differing in bushel weight and seed size. Final Report. Texas Tech University. Anim. Sci. Dept. Lubock, Texas 9409.

Choct, M. and G. Annison (1992). The inhibition of nutrient digestion by wheat pentonsans. *Br. J. Nutr.*, **67** : 123-132.

Hamid, F. H. (2001). The effects of germination and fermentation processes on chemical composition andnutrivival value of low – tauuin grain sorghum. *M. Sc. Thesis*. Faculty of Animal Production University of Khartoum.

Musharaf, N. A. and J. D. Latshaw (1991). Effect of tanin extraction on the feeding value of grain sorghum in broiler starter diets. *Sudan J. Anim. Prod.*, **4** : 53 – 64.

Murphy, T. C., M. R. Bedford and K. McCracken (2005). Xylanase action on non-starch polysaccharides along the digestive tract of broilers. *Br. Poult . Abs.*, 1.38.

Ojewola, G. S., S. N. Ukachukwu and E. I. Okulonye (2006). Cottonseed meal as Substitute for Soya bean Meal in Broiler Ration. *International Journal of Poultry Science* **5**.

Pariza, M. W. and M. Cook (2010). Determining the safety of enzymes used in animal feed. *Reg. Toxicol. Pharmacol.*, **56** : 332-342.

Sharif, M., M. Idrees, N. A. Taukir, M. A. Shahzad, M. F. Khalid, M. Nisa, M. Sarwar and M. L. Khan (2012). Effect of water treatment of sorghum on the performance of broiler chicks. *South African J. of Anim. Sci.*, **42 (2)** : 189 – 194.

Serna-Saldivar, S. O., C. M. McDonough and L. W. Rooney (1991). The millets in Handbook of Cereal Science & Technology (eds Lorenz, K. J. and K. Kulp), Marcel Dekker, pp. 271–300.

Talha, E. E. A. and N. A. Musharaf (2008). The effect of germination of low – tannin sorghum grains on its nutrleutconteuts and broiler chicks performance Pakistan. *J. of Nutrition*, **7 (3)** : 470 – 474.

Torki, M. and M. Farahmand (2007). Use of dietary enzyme inclusion and seed germination to improve feeding value of sorghum for broiler chicks.

Selle, P. H., H. H. Truong, A. Khoddami, A. F. Moss, T. H. Roberts and S. Y. Liu (2016). The impacts of hammer-mill screen size and grain particle size on the performance of broiler chickens offered diets based on two red sorghum varieties. ISSN : 0007-1668 (Print) 1466-1799.

Sheppy, C. (2003). The current feed enzyme market and likely trends. In: M. R. Bedford and G. G. Partridge (Eds.).pp.1-10. Enzymes in farm Animal Nutrition CABI Publishing Wallingford, Oxon, U.K.