The Effect of Magnesium Supplements on Electrolyte Distribution and Plasma Lipids of Broilers

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Zusammenfassung

Wechselwirkungen zwischen der Zufuhr von Mg mit dem Trinkwasser einerseits und dem Elektrolytstatus und den Plasmalipiden andererseits wurden an 23 Abre Acre Broilern studiert. Gruppen von 7 bis 8 Tieren erhielten Standard-Futter und Trinkwasser, das mit 0, 16 und 32 mmol Mg/l (als Mg-Aspartat-HCl) angereichert war, während 3 Wochen. Die Behandlungen wurden gut toleriert. In der höchsten Mg-Gruppe bestand eine Tendenz zu günstigeren Futter-Konversions-Raten und günstigeren Plasma-Lipiden. Aus praktischen und theoretischen Erwägungen erscheint es vielversprechend, diese Studien fortzusetzen.

Summary

Interactions between Mg uptake via drinking water and plasma lipids and electrolyte status were studied in 23 Abre Acre broilers. Groups of 7 to 8 animals received standard food and drinking water containing 0, 16 and 32 mmol Mg/l (Mg-aspartate-HCl) during 3 weeks. Treatment was well tolerated. In the highest of Mg-group, there was a tendency towards improved food conversion rate (FCR) and beneficial effects of increased blood Mg levels on plasma lipids. From practical and theoretical points of view, it seems promising to continue these studies.

Résumé

Les interactions entre la supplémentation de Mg avec l'eau potable d'un côté et l'etat des électrolytes et les lipides plasmiques d'un autre côté étaient étudiées chez 23 cochets du genre Abre Acre. Des groupes de 7 à 8 animaux recevaient une allmentation standardisée et de l'eau contenant 0, 16 et 32 mmol de Mg/l (Mg-aspartate-HCl) pendant trois semaines. Ce traitement était bien toléré. Le groupe qui recevait la supplémentation de Mg plus augmenté prouvait une tendance plus favorable au taux de conversion d'allmentation et aussi aux lipides plasmiques. Considérant l'aspect pratique et théorique, il nous semble prometteur de continuer ces études.

Introduction

Domestic chicken is frequently used as an experimental animal for testing the quantitative and qualitative aspects of the antihypercholesterolemic effect of various compounds [9, 5] and oestrogen-induced hyperlipidaemia that may occur in man [11]. Evidence exists that the process of fat digestion in the bird is essentially the same as in mammals [6]. *Leveille* et. al. [13] found that the reactions involved in fatty acid synthesis are the same in avian and mammalian system, and in addition to this *Chapman* reported in 1980 [3] that lipoprotein patterns in the normal cockerel show marked similarities to human patterns. Magnesium (Mg) is an essential activator of about 300 different enzymes, among others enzyme systems using ATP for substrate. Thus Mg is important in several energy-demanding processes such as cell membrane permeability, neuromuscular excitability, protein, nucleic acid and fat synthesis [4]. However little information is available about interactions between Mg and lipid metabolism. Interestingly some authors also reported that Mg supplementation improved feed efficiency in poultry [2, 8]. In view of this situation the following study was conducted to investigate the influence of Mg supplemented drinking water on food conversion rate, electrolyte distribution and alterations of plasma lipids in broilers.

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Material and Method

23 white Abre Acre broilers (14 males; 9 females) aged ca. 4 weeks weighing between 880 to 1290 g were maintained under identical field conditions. The broilers were randomly divided into 3 groups: The control group (G1, n = 8) was fed with standard food (Mg contents 66 mmol/kg dry weight measured by analysis, protein 19%, and fat 4%) and tap water (Mg contents 0.23 mmol/l measured by analysis) as drinking water ad libitum. The Mg-normal group (G2, n = 7) and Mg-high group (G3, n = 8) were treated with the same food but drinking water was enriched with Mg in form of magnesium-L-aspartate hydrochlorid (MAH). MAH was added in 2 concentrations, 4 g/l and 8 g/l respectively, yielding approximately 16 and 32 mmol Mg/l. Water was offered ad libitum for 3 weeks. Blood collecting was done 4 times with heparinized syringes from wing vein of fasted animals (for 16 hrs) at the starting week (W0), at one week (W1), two

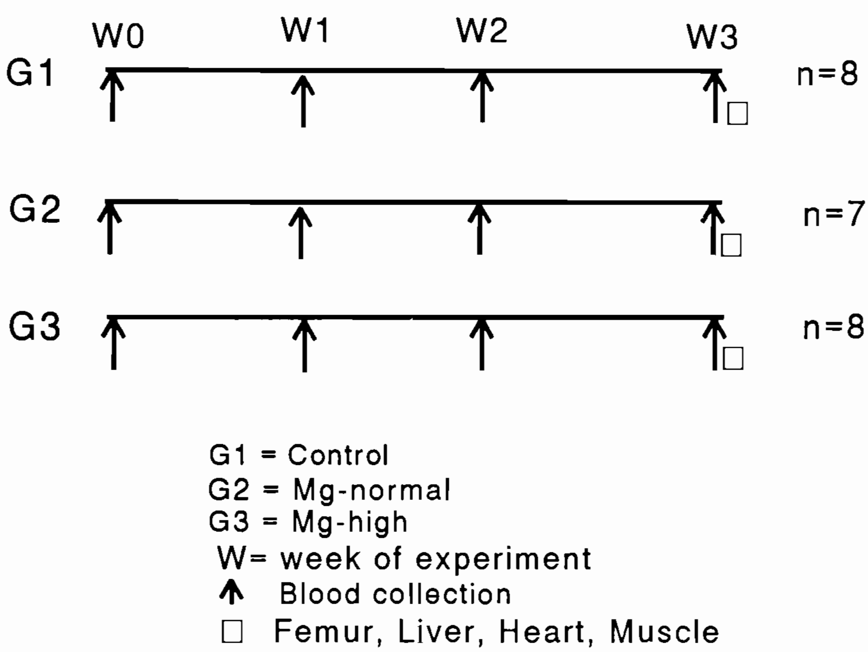


Fig. 1: Flow chart of the experiment.

weeks (W2), and three weeks (W3) after Mg supplementation (see Fig. 1). Totally 92 heparinized blood samples were immediately centrifuged at 2000 rpm for 10 minutes, then plasma of each week (W0, W1, W2, W3) was separated. Plasma and erythrocytes were stored at -20°C until measurements. Total cholesterol (TC), high density lipoprotein (HDL) and low density lipoprotein (LDL) of plasma were measured by CHOD-PAAP method and plasma triglyceride (TG) by GPO-PAP method from Boehringer Mannheim using an UV spectrophotometer, Eppendorf Hamburg, at Hg 546 nm. At the same time plasma and whole blood electrolytes including Mg and Ca were also analyzed. At the end of the feeding time the animals were painless sacrificed with pentobarbital i.c. Then left tibia, left gastrocnemius, right upper lobe of the liver, and the heart muscle were taken for the determination of Mg and Ca. All organ samples and erythrocytes were lyophilized, weighed and ashed. Concentrations refer to the dry matter. The electrolyte measurements in this experiment were done by using atomic absorption spectrometer (AAS) from Perkin Elmer 1100 Überlingen, Germany.

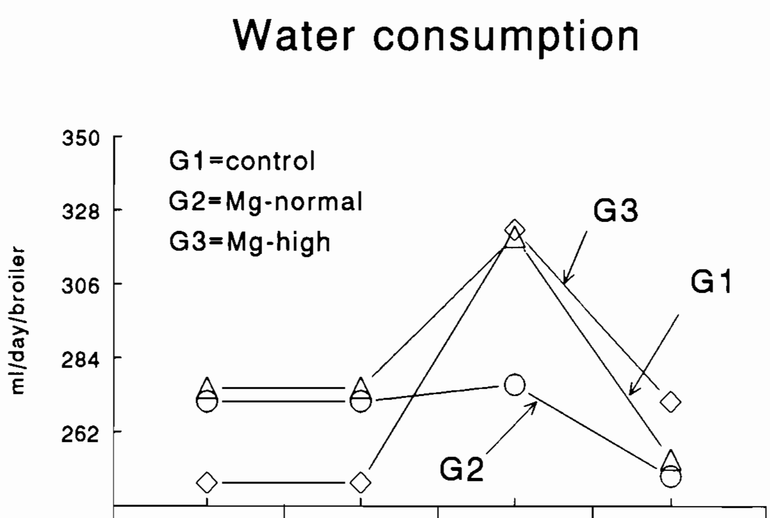
Statistics

Data were analyzed with unpaired and paired Student's t-test by the software programe of Slide Write® Plus version 5, U.S.A. Correlation was tested between whole blood Mg to total cholesterol, whole blood Mg to triglyceride and whole blood Mg to low density lipoprotein. The level of significance was set at 5%.

Results

General development: Drinking water enriched with different concentrations of Mg was well tolerated by the broilers. Softer faeces occurred in some animals of groups 2 and 3, as expected. All broilers survived in acceptable conditions until the end of the experiment. Water consumption increased during the second week (see Fig. 2); Mg uptake via drinking water amounted to approximately 4 mmol/day in group 2, and to 8 to 10 mmol/day in group 3. Body weight increased in all groups. At the end of week 3 it amounted to 1836 ± 220 g, 1714 ± 236 g, and 1948 ± 172 g in groups 1, 2 and 3 respectively. Food consumption was similar (see Fig. 3). Food conversion rate, i.e. the amount of food necessary to increase body weight to the same extent, was most favourable in group 3 (2.52) compared to group 2 and 1 (3.43, respectively 4.89), as shown in Table 1.

Electrolyte distribution: Depending on the Mg content of the drinking water, whole blood and plasma Mg increased



	W0	W1	W2	W3
G1(mmol/d)	0.063	0.063	0.073	0.058
G2(mmol/d)	0.062	4.43	4.51	4.07
G3(mmol/d)	0.057	8.09	10.46	8.80

Fig. 2: Mean daily water consumption and Mg uptake of broilers in the different groups.

Tab. 1: Food conversion rate (FCR) in broiler

	Week 1	Week 2	Week 3
Group 1	1.65	2.18	4.89
Group 2	2.08	2.94	3.43
Group 3	2.02	2.03	2.52

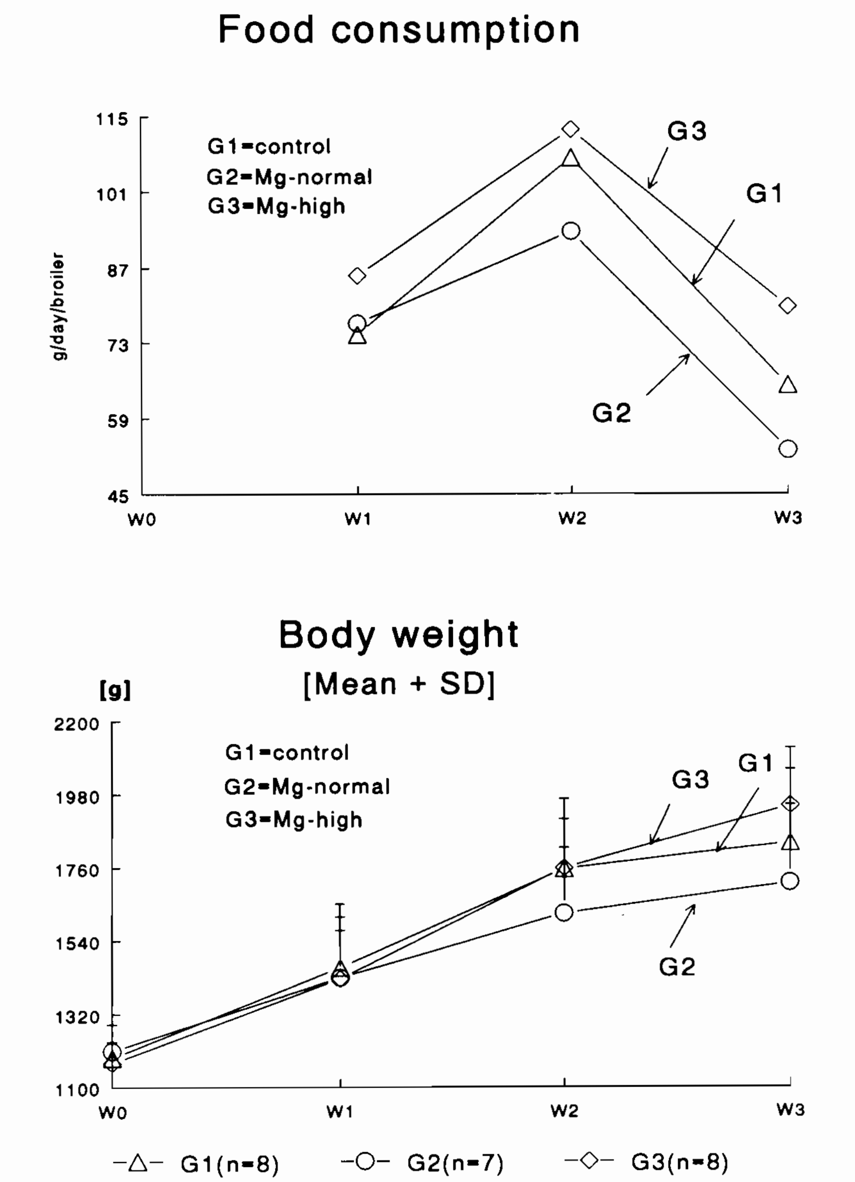


Fig. 3: Mean daily food consumption (top) and increase of body weight of broilers in the different groups (bottom).

during weeks 1 to 3, as compared to the initial values of week zero (see Fig. 4). Surprisingly, the higher Mg concentration (group 3) did not convincingly yield higher Mg levels than group 2. Blood and bone Mg are narrowly related to each other. Therefore it is not surprising that tibia Mg reflects blood concentrations (see Fig. 5).

In Table 2, plasma and tissue Mg and Ca levels are summarized. There is a tendency towards lowered Ca concentrations in heart and skeletal muscle as well as in hepatic tissue.

Lipid metabolism: Levels of total cholesterol (TC), triglyceride (TG), high density lipoprotein (HDL), and low density lipoprotein (LDL) are summarized in Table 3, as well as the quotients of TC/HDL and LDL/HDL. At the beginning of the experiments (week 0), levels amounted to 142-154 mg/100 ml TC, to 36-54 mg/100 ml TG, to 83-85 mg/100 ml HDL, and to 51-58 mg/100 ml LDL. Table 3 shows changes related to the control group G1: Obviously, high Mg offered via drinking water lowers TC, TG, and LDL, whereas HDL is slightly increased. Correspondingly, the ratio of TC/HDL and of LDL/HDL also decreased in group 3.

As the electrolyte shifts and lipid alterations let assume, there is a weak, however significant negative relation between whole blood Mg to TC ($r = -0.2538$) and a more significant negative relation between whole blood Mg to TC ($r = -0.4072$), as depicted in Fig.

Tab. 2: Plasma and tissue electrolytes of broilers (n = 7 - 8) in the different groups (mmol/l, respectively mmol/kg dry matter)

	Plasma											
	Week 0			Week 1			Week 2			Week 3		
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
Mg ±SD	0.79 ±0.07	0.84 ±0.04	0.82 ±0.06	0.91 ±0.07	0.95 ±0.05	0.89 ±0.05	0.81 ±0.06	0.93 ±0.02	0.86 ±0.06	0.79 ±0.06	0.94 ±0.13	0.96 ±0.08
Ca ±SD	2.52 ±0.06	2.49 ±0.17	2.47 ±0.20	2.75 ±0.09	2.72 ±0.14	2.63 ±0.17	2.68 ±0.17	2.69 ±0.12	2.69 ±0.10	2.69 ±0.13	2.72 ±0.18	2.78 ±0.08
	Heart			Muscle			Liver			Erythrocytes		
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
Mg ±SD	39.55 ±2.93	41.05 ±1.99	38.01 ±2.85	44.07 ±3.27	44.03 ±4.92	44.87 ±9.39	30.56 ±1.28	30.58 ±1.71	30.04 ±4.12	10.37 ±0.76	10.46 ±0.65	10.25 ±0.61
Ca ±SD	6.50 ±0.74	6.27 ±0.55	6.27 ±0.61	5.10 ±0.75	5.11 ±0.82	4.97 ±1.43	4.84 ±0.89	5.01 ±1.15	4.55 ±0.88	1.28 ±0.24	1.42 ±0.27	1.27 ±0.17

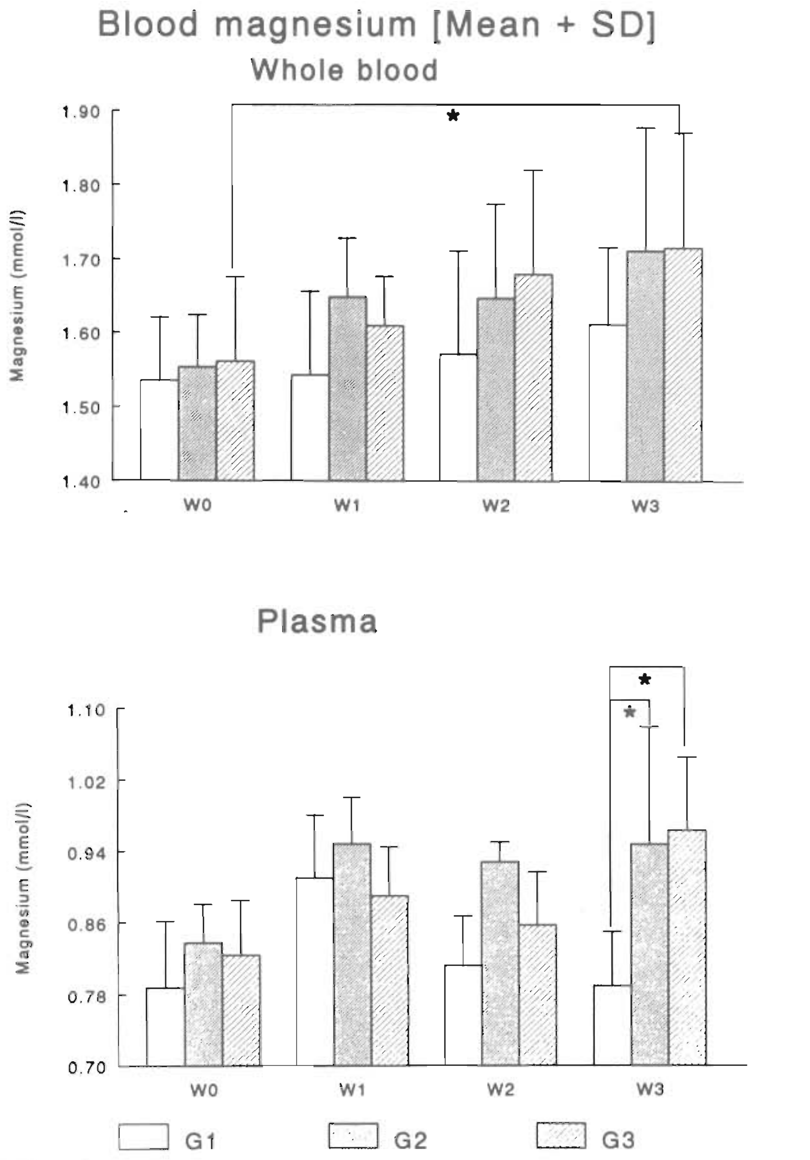


Fig. 4: Magnesium concentrations (mmol/l) in whole blood (top) and plasma (bottom) of broilers in the different groups.

6. In other words, high Mg uptake increases blood Mg and decreases both total cholesterol and triglyceride levels.

Discussion

In 1988 *Grashorn* and colleagues reported on the effect of Mg-supplemented food in broilers [8]. These authors found increased plasma-Mg levels and a tendency towards improved food conversion rate (FCR). In the present experiments increasing amounts of Mg as the MAH were added to the drinking water of broilers. In previous studies of *Meyer* et al [14] and *Rattanatayarom* et. al. [15], it has been shown that rodents accepted this treatment. In fact broilers also tolerate Mg-rich water as drinking water, this in contrast to man who would not accept the bitter taste. As a consequence, Mg-enriched drinking water could be used in future studies on broilers. From a practical point of view, the improved FCR might be of interest, the more since *Atteh* and *Leeson* [2] have reported similar results. At the moment field experiments have been started in the area of Rahchaburee, the farm-area province near Bangkok to evaluate whether or not such a treatment is meaningful. From an experimental point of view it is noteworthy to recognize that the broiler model presented here seems to be suitable for the study of Mg-lipid-interactions. In fact there was a tendency towards more favourable lipid patterns in the high-Mg-

Tab. 3: Plasma lipid alterations in broilers (n = 7 - 8) treated with Mg during 3 weeks presented as the percental changes related to group 1 (G1).

	Week 0			Week 1			Week 2			Week 3		
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
TC (%) ±SD	100 ±11	109 ±11	100 ±12	100 ±10	99 ±16	94 ±10	100 ±17	95 ±13	92 ±10	100 ±24	90 ±15	85 ±11
TG (%) ±SD	100 ±16	108 ±28	100 ±14	100 ±14	100 ±15	109 ±26	100 ±14	96 ±12	87 ±14	100 ±15	87 ±14	87 ±22
HDL (%) ±SD	100 ±13	102 ±14	100 ±10	100 ±12	99 ±12	100 ±9.3	100 ±12	97 ±17	97 ±7.2	100 ±26	96 ±16	107 ±13
LDL (%) ±SD	100 ±19	108 ±18	95 ±22	100 ±11	92 ±28	80 ±15	100 ±20	85 ±22	78 ±17	100 ±20	78 ±23	57 ±26
TC/HDL ±SD	1.7 ±0.1	1.8 ±0.2	1.7 ±0.2	1.9 ±0.2	1.9 ±0.3	1.8 ±0.2	1.9 ±0.3	1.9 ±0.3	1.8 ±0.2	2.1 ±0.3	1.8 ±0.2	1.6 ±0.3
LDL/HDL ±SD	0.62 ±0.2	0.69 ±0.2	0.61 ±0.1	0.92 ±0.2	0.86 ±0.3	0.74 ±0.2	0.92 ±0.2	0.86 ±0.3	0.76 ±0.2	0.92 ±0.2	0.91 ±0.5	0.59 ±0.3

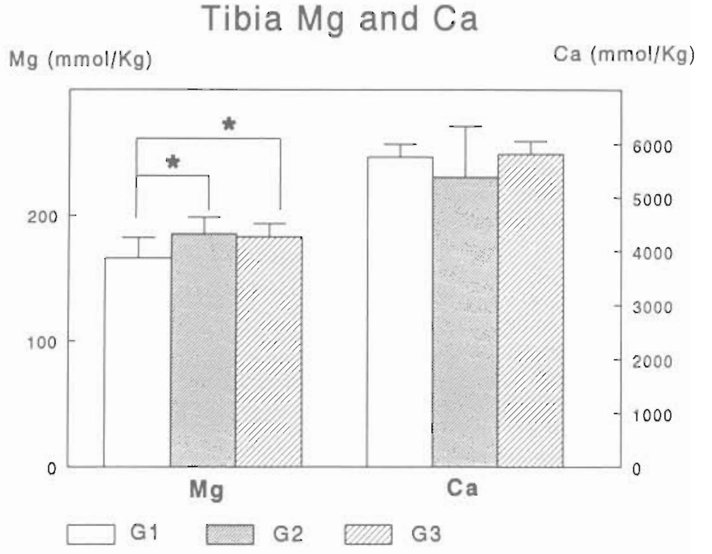


Fig. 5: Skeletal Mg and Ca concentrations of broilers in the different groups.

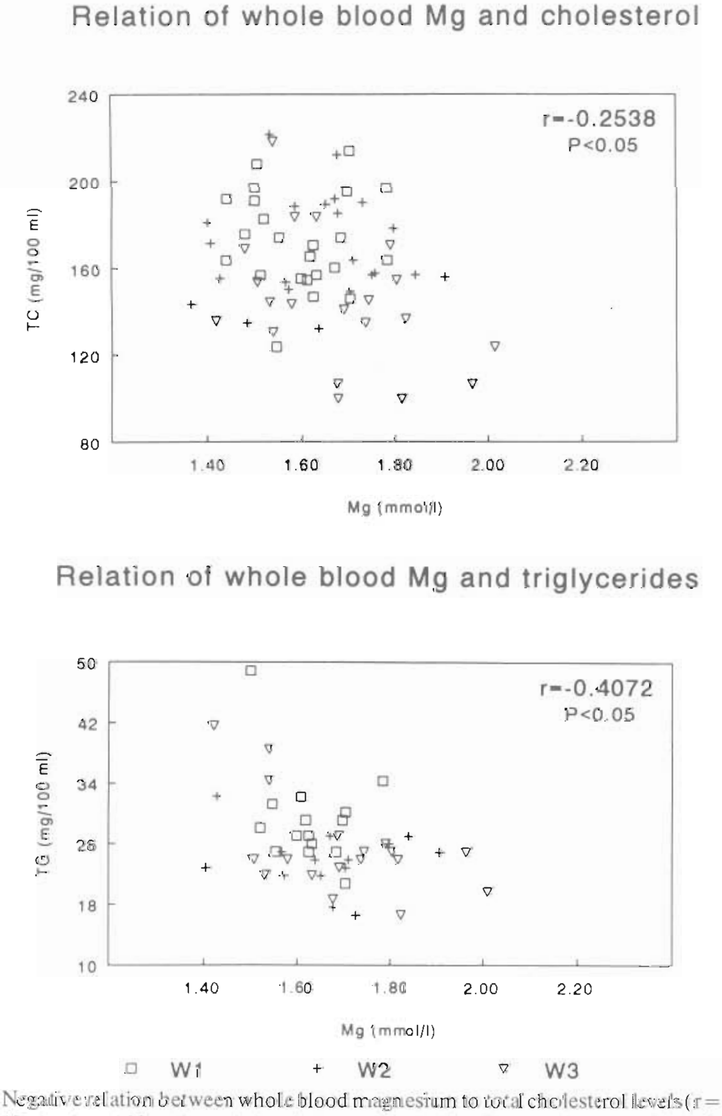


Fig. 6: Negative relation between whole blood magnesium to total cholesterol levels ($r = -0.2538$, $p < 0.05$) (top) and Negative relation between whole blood magnesium to triglyceride levels ($r = -0.4702$, $p < 0.05$) (bottom).

group. In future experiments, conditions should be chosen to provide hypercholesterolemic conditions, as described e.g. by *Grimminger* et. al. [9] or *Kudzma* et. al. [11]. Then again drinking water should be supplemented with Mg. This would probably provide clearer and significant results. Data reported in the literature let assume that plentiful Mg supply exerts beneficial effects on hyperlipidaemia in man [7, 10] and animals [1, 12]. Further studies are necessary to confirm these observations and to elucidate the underlying patho-mechanisms. The broiler model presented here might be a valuable tool for these studies.

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