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THE RABBIT BODY COMPOSITION: METHODS OF MEASUREMENT, SIGNIFICANCE OF ITS KNOWLEDGE AND THE OBTAINED RESULTS. - A CRITICAL REVIEW.

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Abstract

The history of rabbit body composition research and a critical assessment of possible methods, the most important endogenous (species, breed, age, weight, sex, pregnancy and lactation) and exogenous (starvation, diet, level of intake, dietary fiber, diet energy-protein ratio, dietary lysine, starch, hormones) factors influencing body composition are given. As a future goal, the elaboration of an integrated net energy system for the energetic evaluation of the rabbit feeds is determined.

Introduction

Although the rabbit is one of the most important laboratory animals and also a meat, fur and wool producing animal (Cheeke, 1986), few data have been reported concerning body composition of this species. Investigations have focused primarily on carcass composition (Hutchinson and Baker, 1949; Ouhayoun et al. 1979; 1981; Lukefahr et al. 1982; Varewyck and Bouquet, 1982; Butcher et al. 1983; Lobley et al. 1983; Ouhayoun and Cheriet, 1983; Ledin, 1984) and only a few papers deal with the total body composition (Lanari et al. 1972; DeBlas and Galvez, 1975; Parigi-Bini et al. 1978; DeBlas et al. 1977; Fraga et al. 1978; Dehalle, 1981). The method used in all cases was direct chemical determination of the components. In many cases the rabbit was used only as a tool for validation of methods or equipments (Green and Dundsmore, 1978; Klish et al. 1984; Fiorotto et al. 1987). Therefore, this critical review is limited to the problem of body composition and deliberately omits carcass questions.

Nutritional experiments on living animals frequently depend on knowledge of how much of each of the major chemical components is present. Measurement of the relative proportion of the major chemical components during (not only at the end) the experiment requires indirect method(s). Knowledge of body composition has not only a nutritional significance (net energy determination), but also a veterinary one, e.g. the dose required for anesthesia of an animal depends upon the fat proportion of the whole body.

The body composition of an animal is determined by heredity and environment, including the nutrient supply. In this review material relevant to the rabbit is presented, but when data are lacking, other species are also referred to. So the general concepts reviewed offer promise of the refinement of nutritional experiments especially those dealing with the evaluation of feed energy. Presently throughout the world, use of digestible energy is common in rabbit nutrition. However, it should be recognized that the DE value of one feed does not necessarily produce a response the same magnitude as that effected by the same amount of DE from another feed (there is a lack of complete additivity). An evaluation of feeds on the basis of net energy eliminates this problem.

<u>Methods for the determination of the body composition</u> (NRC, 1967; Sheng et al. 1979; Cohn et al. 1982; Kleiber, 1987; Forbes, 1987; Blaxter, 1989; Fekete, 1991). The most direct estimate of body composition is direct chemical analysis, but this does not allow following changes in body composition of the living animal. Therefore, considerable ingenuity has been displayed in devising methods for estimating body composition in living animals: density (Garrett et al. 1959), ^{40}K counting (Belyea et al. 1986), metabolic balance (Belyea et al.

1986), neutron activation, NMR: nuclear magnetic resonance (Kallweit et al. 1989), creatinine excretion, intake of fat-soluble gases, like cyclopropane, xenon, ^{85}Kr, dilution methods using Na (Fébel et al., 1987), K, D_2O (Brown and Taylor, 1986; Fekete and Brown, 1991), THO, urea (Bartle et al., 1987), anthropometry (mostly human), radiography, photon densitometry, computerized tomography, CT (Skjervold et al., 1981; Horn, 1991), infrared interactance ultrasound, near-infrared spectrophotometry (Eisen et al. 1984) 3-methylhistidine excretion (Brown et al., 1987), total body electrical conductivity, TOBEC (Van Loan and Mayclin, 1987; Fiorotto et al. 1987; Fekete and Brown, 1991), bioelectrical impedance (Renden et al. 1988), plasma very low density lipoprotein (Griffin and Whitehead, 1985). None is foolproof and each one has advantages and disadvantages. One has to select a technique the purpose of the study to be performed must be considered, along with the availability of equipment and facilities.

I.The most important endogenous factors, influencing the body composition.

Species

Von Bezold (1857) compared the body composition of mammals, birds, amphibians and fish at various stages of development and demonstrated very characteristic species differences.

Spray and Widdowson (1951) analyzed mice, guinea-pigs, rats, rabbits, cats and pigs at birth and at the end of the suckling period, and the composition of the last four mentioned species was followed through to maturity. Their results confirm Moulton's (1923) conception of chemical maturity, and the conclusion that "though this is valuable, it is not a true generalization, and requires elaboration if it is to be applied in detail.". The main source of differences between the species was fat; compositions of adult fat-free body tissues of rat, rabbit, cat, pig and man were very similar (Table 1). Fekete (1990) found also great differences in the fat and energy content of different rodents. The dry matter of the rabbit contained less fat (18.5 %), than the rat (24.1 %) or the golden hamster (39.3 %).

Breed

It was pointed out (NRC, 1975), that genetically determined differences in ability to digest feedstuffs and in basal metabolism are of such small magnitude as to be of doubtful practical significance. Old and Garrett (1987) stated, that Charolais steers made leaner gains than Hereford steers.

In a trial with suckling rabbits, the New Zealand (middle size) animals had higher total fat content, total energy and lower water content, than Spanish Giant (large size) ones of equal weight and age (Fraga et al., 1978). Even the caloric values of the fat differed: 9.34 Kcal/gram for Giant and 9.14 Kcal/gram for New Zealand breed. The authors hypothesize, that the differences in body composition of the two breeds at the same age may relate to a difference in physiological age.

Age/Weight

Moulton (1923) found that mammals become chemically mature at different ages and that the proportion of total life span elapsed prior to attainment of chemical maturity is approximately 4% for all species investigated: rat 50 days, guinea pig 50 days, cat 100 days, dog 200 days, swine 150-300 days, cattle 150-300 days and man 500-1000 days. Chemical maturity is the age at which the concentration of water, protein and ash in the fat-free body becomes constant. In this respect there is a difference at birth, i.e. the cattle and guinea pigs are more developed chemically than are man, dog, cat, swine and rabbit.

The above-mentioned work and the other early studies demonstrated that the concentration of the water decreases and ash and protein content increase during maturation. During fattening there is a replacement of water by fat. Reid et al. (1955) propose a correction of protein concentration according to the age.

Spray and Widdowson (1951) investigated rabbit body composition at different stages of life. Young (15-35-day-old) rabbits were fatter than newborn and adult rabbits contained more ether extract than growing (2-4-month-old) animals (Table 2).

DeBlas and Galvez (1975) used the comparative slaughter technique to determine energy and protein requirements for growth in the very young rabbits. Giant of Spanish breed rabbits were slaughtered in groups at birth, 10, 20, 30, 40, 50 and 60 days of age. Crude protein and gross energy content of the total body dry matter decreased with the age; that of the ash increased. (Table 3). On the other hand, the energy content of the dry weight gain increased (5.18, 5.52, 5.52, 5.47 and 5.89 kcal/gram, according to the sampling times). They calculated the protein deposition by N*6.25, which could cause some errors. They found a relationship between the energy content of the empty body (y, kcal) and the empty body weight (x, gram): $y = 1.734\,x - 88.536$.

As a continuation of the described trials, DeBlas et al. (1977) investigated the influence of weight and age on body composition in doe rabbits from 3 to 5 months old. Dry matter, fat and energy concentration of the body increased and the protein and ash content decreased parallel to the age. (Table 3).

Although live weight did influence body composition, correlations between live weight and body dry matter, fat, ash, protein and energy content were only medium . Analyzing the composition of the weight gain, they stated that the net energy requirement of 1 gram weight gain increases with the weight, but do not vary with different growth rates. Concerning the net N-requirements per gram body weight gain, no variation was observed with either weight or growth rate. The appropriate value is 3.2 gram nitrogen retention in 100 gram live weight gain.

Live weight at slaughter accounted for the greatest part of the variation of water, fat, protein, ash and energy content (Fraga et al., 1983). As the slaughter weight increased, the percentage of water in empty body decreased, and that of fat increased. An increase in 1 gram of daily weight gain resulted in an increase of 0.12 percentage units of fats and of 0.01 kcal/g empty body, and a reduction of 0.009 and 0.05 percentage units of nitrogen and water.

To clarify the joint effect of weight and age, using analysis of covariance, new equations were developed for the estimation of the body composition. (x = live weight, kg, DM = dry matter):

Dry matter $= 100/(3.70-0.31x) + c$
where $c = c_1, c_2$ or c_3,
$c_1 = 0.84$ (for the age of 3 months)
$c_2 = 0.74$ (for the age of 4 months) and
$c_3 = -2.81$ (for the age of 5 months)

Ether extract (% DM) $= 100/(4.06-0.63x) + c$
where $c_1 = 0.38$ (3 months)
$c_2 = -2.88$ (4 months)
$c_3 = 3.55$ (5 months)

Crude protein (% DM) $= c - 6.66\,x$
where $c_1 = 76.63$ (3 months)
$c_2 = 78.98$ (4 months)
$c_3 = 74.35$ (5 months)

Gross energy (kcal/g DM) = 100/(18.91-1.04x) + c
where c_1 = - 0.014 (3 months)
c_2 = - 0.122 (4 months)
c_3 = 0.161 (5 months).

When all the data was treated as one pool, the composition of the dry fat-free body was practically constant, containing 13.98 % nitrogen and 13.76 % ash. Between water (x, percentage of water in live weight) and fat (y, percentage of fat in live weight) they established a good ($R^2 = 0.73$) correlation: $y = 61.51 - 0.85\ x$. The energy concentration (GE, kcal/kg DM) can be calculated by means of the fat (x_1, % in live weight) and protein (x_2, % of live weight):

GE = 2.982 x1 - 2.022 x2 + 6547; R2 = 0.84 or
GE = 9.403 x1 + 5.789 x2 .

As the latter concerns, Fekete and Brown (1990) established, that the fuel value of the whole rabbit body differs according to the feeding.

In another trial, comparing the New Zealand and Spanish Giant suckling rabbits, Fraga et al. (1978) confirmed, that the age influenced body composition and was highly correlated to weight. This influence was significant for every body constituent, except ash, at all ages. There was a significant decrease with age in water content and an increase in nitrogen and ash content. From the age of 25 days the composition tends to stabilize at both breed.(Table 4). At 29 days of age, the N-content of the fat-free dry body presented a maximum (13.00-13.10 % DM), and the ash content a minimum (14.18-14.52 % DM). In the subsequent period these values returned to those of new-born rabbit, i.e. 12.62-12.65 % N of DM and 15.69-16.20 % ash in DM.

Fekete and Brown (1990) compared adult and growing (5-10-week-old) New Zealand White rabbits, fed with different diets. They found significance differences between the two age groups (Table 7a).

The TBW as a percentage of FFWW (fat-free wet weight) appeared to stabilize in the rabbit between the 20 and 30 days of age.

Sex

Rathbun and Pace (1945) in their fundamental work on guinea-pigs reported demonstrable sex differences in body composition when the animals were compared on a fat-free body weight basis. The female guinea-pigs averaged 4.7 per cent more fat than the males. Shebaita (1977) established that the water percent of the mouse fat-free body at mature age decreased with increasing fat percent in the male, while in the female was constant (criticism of the mechanical use of the so called "water concept").

Spray and Widdowson (1951) established that growing (from puberty) and adult female rabbits were generally fatter and had a higher concentration of iron than males. They stated that since the concentration of iron in the liver of female rabbits was no higher than in male rabbits of the same age, any sex difference in the concentration of Fe in the whole body must have been due to a difference in extrahepatic tissues.

To be able to critically evaluate the influence of sex on body composition, one must cite the results of other species. Garrett et al. (1971) found that heifers were dryer, with more ash and nitrogen than steers. These sex differences were small, but significant. On a fat-free basis, barrows contained more water (76.7 vs 76.3 %) and less protein (19.9 vs 20.3 %) than gilts did (Chiba et al., 1990). Data of Fomon et al. (1982) demonstrated that there is not a sex difference in throughout infancy and childhood of the human. Adolescent girls and mature women contain more fat than do boys and men. The tendency resembles that of rabbit data reported by Spray and Widdowson (1951). Reid et al. (1955) did not find sex differences in cattle. Ferrel et al. (1979), using comparative slaughter procedures, found rams with more water (12.3 %) and protein (9.4 %) and less fat (31.7 %) than ewes.

After the data of Fredericks and Cramer (1976), female rabbits had significantly more fat in bodies and higher cholesterol in blood plasma.

In their experiment with suckling (0 to 35 days of age), Fraga et al. (1978) found no sex influence on body composition of suckling rabbits. On the contrary, they found a sex effect on the proportion of N in the bodies of growing (4-12-week-old) rabbits (Frage et al., 1983). Males had 1 % more nitrogen than females at the same body weight. Males contained less (0.8 %) fat than females.

Fekete and Brown (1992) detected an important sex difference in major body chemical components (Table 7b), which must have been due to age of the animals; i.e. in this trial the age was older.

Pregnancy and Lactation

Spray (1950) investigated by direct chemical analysis the effects of pregnancy and lactation on body composition of the bodies of mothers and their young. The newborn rat and mouse contained more water (86.15 and 83.20 %) and less fat (1.14 and 2.03 %) than the guinea-pig did (70.80 % and 10.00 %, water and fat respectively). For dog puppies the DLG (1989) gave 79.80 % water and 1.40 % ether extract. Corresponding rabbit (Fraga et al., 1978) data are very close to those of mice.

In Spray's trial, during pregnancy rats stored more protein, fat, potassium, zinc and copper in their own bodies than they transmitted to the fetuses and adnexa. They also retained more Ca and P than non-pregnant animals. On the other hand, during lactation does lost 65.5 % of the protein they had retained during pregnancy and more than all the fat, calcium and phosphorus. The tendency in mice was the same, but the reduction of the fat content after delivery was smaller. Guinea-pigs transmitted relatively more protein, fat, calcium and phosphorus to their young during pregnancy than did rats or mice, and during lactation correspondingly less.

The placenta contained more water (83.9 vs 79.4 %) and ether extract (2.0 vs 1.4 %) and less protein (12.2 % vs 14.5 %), ash (1.0 vs 2.7 %) and N-free extract (0.9 vs 1.6 %), than did newborn puppies (DLG, 1989).

Kamphues (1985) studied energy, nitrogen and mineral accretion in the fetus, placenta, uterus and mammary glands of does of 3.5-4.7 kg body weight. Relative weight of the fetuses at Day 15 was 0.007 % of the mother's live weight and increased to 1.198 % at the end of the pregnancy. Having recorded not only changes in the weight and composition of fetuses, but also those of the placenta, uterus and mammary glands, the author could calculate the daily accretion of nutrient and energy in the last 8 days of pregnancy (Table 5).

Supposing that the k_c (efficiency of energy utilization for conceptus energy gain) was 0.25, the maintenance requirement was 95.6 kcal/$W^{0.75}$ and 3 gram digestible crude protein and the efficacy of protein transformation into fetus was 60%, he calculated the requirements of the pregnancy, concluding that does cannot meet their energy requirements by feeding (see Lebas, 1979) and that mobilization of body reserves is inevitable. In breeding ewes, Robinson (1983) proposed a value of 0.145.

Parigi-Bini et al. (1990a) studied the energy and protein retention of does during 1st lactation. They used comparative slaughter technique, comparing the non-pregnant control to the Days 21 and 30 of pregnancy. During the first 21 days, average gain (building of own tissues) in pregnant does was 180 grams, plus 193 grams for weight of the pregnant uterus. Composition of body weight gain and that of the uterus were as follows: 31.1 vs 85.00 % water, 24,4 vs 9.30 % crude protein, 36.1 vs 4.7 % ether extract and 8.4 vs 1.0 % ash respectively. The total energy retention was in an average 980 kcal/animal.

In the last 10 days of pregnancy there was a catabolism in the mothers bodies; the uterus and the fetuses showed intensive gain (647±58 grams), mostly water (81.71 %), protein (11.25 %), with some fat (5.15 %) and ash (1.89 %). As a final result, empty body weight gain of pregnant does during gestation was positive (90 grams, 575 kcal). Protein efficiency was higher in the pregnant (17 %) than in the non-pregnant control (5 %). The digestible energy requirement for maintenance (98.5 kcal/day/W0.75) and efficiency of energy utilization for gestation (i.e. doe's weight gain plus pregnancy: 44.7 %) were not significantly altered by this physiological status. The efficiency of protein transformation (retained N/digested N, %) in pregnancy was 16-17%. The authors explained the physiological changes by the redoubled glucacon level.

As a continuation of the described work, Parigi-Bini et al. (1991) investigated the chemical composition of milk and body in 27 non-pregnant, lactating does, using a comparative slaughter technique. Mothers and their young were killed just after parturition and on Days 14 and 29 of the lactation. During this first lactation, body weight increased by about 170 grams, but empty body weight decreased by 223 grams, i.e. the energy balance was negative. It reflected increase in water content (from 59.8 to 66.9 %) and reduction in fat (from 16.0 to 7.5 %) and caloric value (2.59 vs 1.92 kcal/gram of body). Efficacity of energy transformation for milk production was 67-72 % . Energy content of the milk derived 80% from the diet and 20% from mobilization of adipose tissues.

Partridge et al. (1986) studied pregnant and lactating does, feeding them high and low energy diets. After parturition, litter sizes were standardized to six. The bodies of the high energy diet does contained more fat (49.6 % vs 37.0 % of DM) at parturition. Pregnancy diets had no effect on litter size at birth, but litter weights and the mortality were significantly higher in does fed the high energy pregnancy diet. The lactation diet did not affect milk composition, but the pregnancy diet did. Does offered the high energy pregnancy diet produced milk of higher fat level (12.3 vs 10.5 % for the high and low energy pregnancy diets, respectively). Body composition data (Table 6) show that fat was usually mobilized in early lactation and gained as lactation progressed. This tendency was independent of dietary treatment.

The derived partial efficiency of dietary ME for milk output (k_m) ranged from 0.34 to 0.64, with most around 0.5, regardless of diets. The partial efficiency of utilization of dietary energy for milk output and maternal tissue gain was lower (0.65) than reported earlier (Partridge et al., 1983.). The estimated maintenance energy requirement (150 kcal ME/$W^{0.75}$) also differed from the previously described 101 and Lebas' proposed 106 kcal ME/$W^{0.75}$ (Lebas, 1989) too. The explanation must be found in the differences between the strains, diets and techniques used.

II. Exogenous factors, influencing the body composition

Starvation

Kleber (1975) described the Terroine et al. (1924) observation that starvation in mice increased body water and decreased body protein and fat but (except for fat) only slightly.

Asghar et al. (1981) found that maintenance and sub-maintenance feeding, compared to ad libitum, resulted in increase in muscle water content in the growing rabbit.

Diet (generally taken)

Spray and Widdowson (1951) summarized previous results about the effect of various diets on body chemical composition in the rabbit. It was demonstrated that bodies of a potato-fed group contained much more fat than those of weed or hay-fed groups. Fekete and Brown (199?) found the bodies of oat-fed rabbits much fatter than those of rabbits fed alfalfa pellets (Table 7a), independent of age and sex. The caloric value of ether extract from the oats-fed rabbits was 9.063, and that of the alfalfa-fed 8.925 kcal/gram.

On the contrary, the type of starter feed, given between the age of 20 to 35, had no influence on body composition in the trial of Fraga et al. (1978).

Fraga et al. (1983) reared growing rabbits on 12 different diets. Although the separate (independent) effect of dietary fiber and protein on body composition was not significant, dietary treatment influenced composition (see energy-protein ratio).

Level of intake

Lacking sufficient rabbit data, it is interesting to note results of Old and Garrett (1987), who found that steers fed ad libitum used energy less efficiently for gain than steers of lower intake (i.e. maintenance, 70 and 85% of ad lib.). Gains of the 70% ad libitum group were leaner than those of the 85 and 100% ad libitum groups. However, final body composition was not altered by level of energy when the animals were slaughtered at equivalent weights.

Ledin (1984) reported that restricted feeding (60% ad libitum consumption) produced carcasses of lower fat (4.56-4.62 vs 8.9-13.18 % of soft tissue gain) and of higher protein (20.26-20.66 vs 18.06-18.35 % of soft tissue gain) content. After refeeding, the carcasses had still lower fat concentration, equivalent percentage of protein and a higher content of water.

Dietary fiber

Contrary to Fraga et al. (1983), Spreadbury and Davidson (1978) reported that dry matter content of the body and energy stored as body fat fell significantly as fiber concentration in the diet increased. These diets contained more fiber (3.9-27.8 % acid detergent fiber) than those used by Fraga et al. (1983). In a similar experiment with young pigs, not only body fat concentration but also nitrogen decreased (De Goey and Ewan, 1975).

Diet energy-protein ratio

Dehalle (1981) studied the effect of dietary energy-protein ratio (49 or 56 gram digestible protein/1000 kcal DE) in rabbits, using two dietary energy levels (2320 and 2730 kcal DE/kg). The energy concentration was changed by straw and starch supplementation. Body weight at slaughter of animals under the 4 treatments averaged 2.0 kg. Dry matter concentration of rabbits on the high energy diet was higher 0.95-2.61 percent units. The protein and ash content of body dry matter did not differ between treatments. Rabbits of the high-energy diets retained more fat (24.4 vs 23.1 % DM) in their body.

Fraga et al. (1983) reared growing rabbits on 12 diets of variable energy to protein ratios. E/P (kcal of digestible energy/gram of digestible crude protein) values of diets were linearly related to the proportion of body N and body fat.

Dietary lysine

Sibbald and Wolynetz (1986) found that carcass protein gain in broiler chickens increased with dietary lysine. Changes in carcass fat were converse, but not so clear, than those in protein, owing to the great variability. The lysine effect on body composition was independent of energy intake. Unfortunately, there is no corresponding rabbit data.

Starch

Parigi-Bini et al. (1990b) carried out experiments with growing rabbits, using diets of low (17.0 % DM) and high (25.3 % DM) starch, with practically equivalent protein (17.3 % DM) and crude fiber (16.6 and 15.7 % DM) concentration. Differences in starch level were set by changes in barley, wheat straw/alfalfa meal and wheat bran. Neither nitrogen balance nor chemical composition of empty body was affected by treatments.

Hormones

Fredericks et al. (1976) proved that glucagon injections altered body fat content in rabbits. Brown et al. (1989) reported that total body fat concentration reduced the effect of somatotropin treatment in dairy cows.

Lobley et al. (1983) treated growing rabbits with 10 mg trenbolone acetate injection. Treatment improved weight gain and nitrogen retention) with a simultaneous decrease in non-protein energy (fat) gain (7.4 vs 5.7 MJ). Treated does contained approximately 50 gram more protein and 40 gram less fat than controls. The results could be explained by a lower urinary N excretion. Teated animals had a lower energy content per unit empty body (2127 vs 2318 kcal/kg). In the steroid-treated does, some masculinization occurred.

Parigi-Bini et al. (1990c) fed growing rabbits 1, 50 and 250 μg/animal/day clenbuterol (ß-2 agonist) for a period of 17 days. The higher dose of clenbuterol significantly improved N-retention (61.7 vs 50-53 % of digested N); the digestibility of nutrients did not change. The water and protein concentration of net gain increased by 21.0 and 27.6 %, that of the fat decreased by 12.5 %. Total energy retention remained unchanged. There were no sex differences in the reaction.

III. Obtained results. Future trends

In early works on mammal (including the rabbit) body composition, Moore (1946) and Spray and Widdowson (1951) used simple desiccation for measurement of total body water. Later, Foy and Schnieden (1960) measured total body water of rabbits by a tritiated water dilution technique. Fébel et al. (198?) used 24Na and Fekete and Brown (1991) a D2O dilution method. TOBEC (total body electrical conductivity) has been used by Fiorotto et al. (1987) and Fekete and Brown (1991). Sheng et al. (1982) pointed out the underestimation of the TBW (total body water) by earlier investigators.

After De Blas and Galvez (1975), the net efficiency of use of metabolizable energy for gain is 55 %, i.e. approximately 1.60 kcal/gram live-weight. Parigi-Bini (1988) supposed the efficiency of digestible energy transformation of protein to be 38-44, and of fat 64-70 %. Partridge et al. (1989) estimated the degree of digestible energy transformation above maintenance for body gain to be 47%. Harris et al. (1985) used growth test, balance and calorimetry technique to study the N and energy requirements of the rabbit. The apparent digestible nitrogen requirement of daily maintenance was 0.442 g/kg $W^{0.75}$. The standard metabolic rate was 85.8 and daily maintenance DE requirements averaged 114.7 kcal/$W^{0.75}$. Ledin (1984) reported that growing rabbits retained 3.93-7.64% of gross energy intake and 8.51-16.36% of protein intake.

Lee (1939a, 1939b) published detailed data about rabbit basal metabolism. Fekete and Gippert (1986) measured the digestibility of nineteen important rabbit feedstuffs. Evans (1982) compiled data of 1,224 individual observations and computed the maintenance DE requirement:

$$DE_m \text{ (kcal/day)} = 112\ W^{0.818}\ ;\ r = .936.$$

Live weight was the primary determinant of the DE required for unit of weight gain:

$$DE_g \text{ (kcal/g)} = 2.456\ W^{0.763};\ .r = .877.$$

The inclusion of age and average daily gain improved somewhat the precision of the prediction equation.

Parigi-Bini and Cesselli (1977) proposed for the estimation of the energy, excreted in urine (y, kcal/kg) from N concentration (x, % N in urine):

$y = 124.04\,x - 1.75$; $r = .98$ and

the daily urinary energy losses (y, kcal/24 h) can be calculated by the excreted urinary N (x, g N/24 h):

Parigi-Bini and Dalle Rive (1978) determined the ME requirement for body gain, i.e. 12.17 kcal ME/gram protein and 13.12 kcal ME/gram fat retention. Using diets of varying protein and fat levels, Reid et al. (1980) estimated the DE requirements of protein and fat gains to be higher (5.32 and 9.76 kcal/gram, respectively). Butcher et al. (1983) determined the ME requirement of live-weight gain: according to the diet energy concentration and the actual body weight was between 2.06-4.13 kcal ME/g live-weight gain.

Parigi-Bini et al. (1978) using comparative slaughter technique, determined the daily net energy requirements of the growing rabbit for maintenance and gain (y, NEm+g, kcal empty W0.75) in function of empty body gain (x, g/24 h):

$y = 2.37\,x + 69.49$ (in Weeks 0-5) and
$y = 2.48\,x + 58.04$ (in Weeks 3-7).

They estimate the DE requirements for maintenance of 115.7 kcal/$W^{0.75}$/day and calculate a DE efficiency of 44.2 and 70.2 % for energy retained as protein and fat, respectively (Parigi-Bini and Xiccato, 1986).

Fraga et al. (1989) gave the energy requirements of maintenance of pregnant and lactating does of 108 and 113 kcal DE/$W^{0.75}$. The mean cost of pregnancy and lactation were 6.04 kcal/gram of live-weight loss at parturition and 2.7 kcal DE/gram of produced milk. For the lactation period, Parigi-Bini et al. (1991) presented a daily maintenance requirement of 103.3 kcal DE/W0.75. They suggested an efficiency of DE utilization for milk production of 63 %, and for body energy of 81 %. The efficacy of digestible protein transformation for body protein or for milk was 77 and 59 %, respectively. The daily maintenance requirement of digestible protein was 3.73 gram/$W^{0.75}$. Taking calorimetric measurements at different environmental temperatures, Jin et al. (1990) found the maintenance energy requirements of growing rabbits to be 85.3 kcal /kg$W^{0.75}$ and availability of ME for gain (kg) 0.44. The kg agrees well with an efficiency of 0.45 reported by Parigi-Bini et al. (1985) and that of 0.47 given by Partridge et al. (1989). The maintenance requirement reported by the last authors was 86.5 kcal/$W^{0.75}$.

Future goals for the rabbit nutritionist should be the reprocessing of data and confirmation of results, collection of data regarding requirements of the rabbit in different physiological and production stages and the energetic value of feedstuffs, and as an integration - creation of a net energetic system for evaluation of feed energy.

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