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Effect of Cats' Grooming Behavior on Apparent Digestibility in Domestic Cats

고양이의 그루밍 행동이 고양이 외관상 소화율에 미치는 영향

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Summary

The Ministry of Agriculture, Food and Rural Affairs (MAFRA) announced that the number of domestic cat households in 2015 was increased by 63.7% compared to 2012, according to a national survey of public awareness about animal care. This result suggested that the negative perception of cats was reduced and the behavior of independent cats was in harmony with modern life patterns.

Cats are engaging in paw licking and face washing as well as licking the pelage in their normal life. A cat can spend approximately 25% to 30% of its time on grooming (Hart, 1976b; Panaman, 1981). Some cats have been observed to spend up to one-third of their awake time for grooming (Loureiro et al., 2014). Daily hygiene routine of grooming in cats results in the formation of hairballs, or trichobezoars when the animals are licked and ingested their own hair (Loureiro et al., 2014). Cats can generally get rid themselves of this problem by retching until the hairball is vomited.

This experiment was conducted to evaluate the time budget and organization of grooming both in short-haired and long-haired cats. And the other purpose of this experiment was to assess the effect of grooming behavior of cats on apparent digestibility in domestic cats (*Felis catus*) by comparing the apparent digestibility of domestic cats using hair-included-feces and hair-removed-feces.

A total of 10 adult domestic cats, average 4.3±0.89 kg body weight and average 3.5±1.38 year, were used for behavioral observation.

There was no significant difference between long-haired cats and short-haired cats in behavioral time budget and organization of grooming.

A total of 14 adult domestic cats, average 4.5±1.21 kg body weight and average 3.3±1.38 year, were used for nutrient digestibility trial. The treatments of digestibility trial were HI; hair-included-digestibility and HR; hair-removed- digestibility. The apparent nutrient digestibility using hair-removed-feces was higher than hair-included-feces. Therefore, the digestibility of dry matter, crude protein, crude ash, ADF and NDF has been underestimated approximately 6%, 7%, 15%, 12% and 10%, respectively when calculated using conventional digestibility method for domestic cats. Because of the chemical composition of hair included in feces, the nutrient digestibility using hair-removed-feces was higher than that of hair- included-feces. The nutrient digestibility between long-haired and short-haired cats had no difference when it was calculated with hair-included-feces. However digestibility of NDF and amino acid in long-haired cats showed higher than that of short-haired cats approximately 4-8%. Therefore, this experiment demonstrated that the presence of hair in the fecal samples should be considered before calculating the apparent nutrient digestibility of domestic cats (*Felis catus*).

Key words : Apparent nutrient digestibility; Behavioral observation; Domestic cats; Grooming Behavior; Hair included in feces

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Ⅲ. Experiment

List of Abbreviation

ADF	Acid detergent fiber
ALA	Alanine
ARG	Arginine
ASP	Aspartic acid
BW	Body weight
CP	Crude protein
CYS	Cysteine
DM	Dry matter
GLU	Glutamic acid
GLY	Glycine
LEU	Leucine
MAFRA	Ministry of Agriculture, Food and Rural Affairs
NDF	Neutral detergent fiber
SER	Serine
THR	Threonine

Ⅰ. General Introduction

Grooming is a frequently occurring and commonly studied behavior of rodents, bovids and non-human primates. Another taxonomic group known for frequent grooming is small felids, including domestic cats. (Eckstein and Hart, 2000). Cats engage in paw licking and face washing as well as licking the pelage. Since cats typically draw the keratinous cornified papillae of the tongue over the surface of the pelage, a large amount of hair was ingested while licking (Eckstein and Hart, 2000; Weber et al., 2015).

Grooming serves several purposes. First, removal of loose hair is necessary to keep the coat unmatted and free from dander to maintain healthy skin. Second, grooming removes ectoparasites (Hart, 1990; Hart, 1997). Third, grooming also removes dirt and stale oil, maintaining insulating capacity of the pelage and temperature control (Eckstein and Hart, 2000).

A cat can spend 25% to 30% of its time on grooming (Hart, 1976b; Panaman, 1981). Some cats have been observed to spend up to one-third of their awake time grooming (Loureiro et al., 2014). According to Eckstein and Hart (2000), domestic cats spent 50% of the time budget sleeping and resting. Oral and scratch grooming accounted for 4% and 0.1%, respectively of the overall time budget or 8% and 0.2%, respectively of non-sleeping resting time when grooming was possible.

Information on complete 24hour time budgets for quantitative behaviour assessments of single caged cats is surprisingly limited. Carlstead et al. (1993) reported information on durations spent alert/awake and in exploratory/play behaviour. However, other reports (De Monte and Le Pape, 1997, Kry and Casey, 2007, Ellis and Wells, 2010) are based upon limited observations during only part of a 24-hour day. There have been a number of sleep studies of cats in single cages that have shown that cats can sleep for 48-55 percent, are drowsy for 14-28 percent, and alert and active for 18-33 percent of a 24-hour day (Lancel et al., 1991; Ellis et al., 2014).

Daily hygiene routine of grooming in cats results in the formation of hairballs, or trichobezoars when the animals lick and ingest their own hair (Loureiro et al., 2014). The ingested hair is moved through stomach and intestines by peristalsis and hair becomes entangled into a solid mass (Debakey and Ochsner, 1938). Specifically, it has been reported that feline hairball formation may be associated with long-haired cats or cats that display frequent grooming and swallowing of hair (Ryan and Wolfer, 1978). Usually ingested hair is eliminated in feces but large quantities can accumulate in the digestive tract forming trichbezoars (or hairballs) that can cause digestive problem (Weber et al., 2015). According to the survey (Cannon, 2013), based on 48 short-haired cats, there was an overall incidence of hairball vomiting of approximately 10% in healthy short-haired cats. For cats that regularly or intermittently suffer from hairballs, few studies for developing preventive treatment have been published (Dann et al., 2004; Beynen et al., 2011; Loureiro et al., 2014). Diets generally contain increased levels of soluble and/or insoluble fiber with the aim of increasing the passage of hair through the gastrointestinal tract and in feces without causing obstruction or constipation, as well as minimizing formation of hairballs in the digestive tract (Weber et al., 2015).

According to Harkey (1993), human hair (depending on its moisture content) consists of approximately 65-95% protein, 15-35% water, and 1-9% lipids. Cat (*Felis catus*) hair was determined by conventional 24h acid hydrolysis and calculated that crude protein make up approximately 67% and amino acids make up 0.86% of the total weight of cat hair (Hendriks, 1998a). The amount of hair found in the feces was 25-75mg/kg body weight per day (Hendriks, 1998b). The trichobezoars in feces were approximately 87-143mg per cat per day and 4.7-11mg/g feces DM (Lourciro et al., 2014). Therefore, the large amount of hair normally present in the feces of the cat may influence the determination of protein digestibility in domestic cats (Weber et al., 2015). As hair was shown to mainly consist of amino acids (Hendriks et al., 1998a), the digestibility of amino acids may be underestimated. This may be particularly significant for the amino acid cysteine, because cysteine is found in high concentrations in cat hair (Hendriks et al., 1998a).

The aim of the current study was to use simultaneous measurements of quantitative and qualitative behaviour to provide a 24-hour time budget for grooming in short-haired-cats and long-haired-cats. The other purpose of this study was to assess the effect of grooming behavior of cats on apparent digestibility in domestic cats (*Felis catus*) by examining the time budget for grooming in short-haired and long-haired cats and comparing the apparent digestibility of domestic cats using hair-included-feces and hair-removed-feces.

II. Literature Review

1. Introduction

1.1 Recent situation of pet industry in Korea

According to the industry, the domestic market size for companion animals is estimated to reach 2.3 trillion won this year and 6 trillion won in 2020 from 1.8 trillion won last year. Especially, pet food market, which is a core industry, has been growing steadily as well, due to well-being. The industry predicted that the domestic pet food market will double to 600 billion won by 2020, which is about 320 billion won in 2012.

The well-being of the companion animal market has increased the proportion of spending on companion animals. According to the Korea Consumer Agency, the average expenditure of companion households on companion animals was 135,632 won per household per month in 2015. Among them, 40.3 percent, or 57,493 won, was for food expenses such as feed and snacks.

According to the Ministry of Agriculture, Food and Rural Affairs (MAFRA) last year, the proportion of households with domestic companion animals increased from 17.9% in 2012 to 21.8% in 2015. The Ministry announced that the number of domestic cat households increased by 63.7% compared to 2012, according to a national survey of public awareness about animal care in 2015. This suggests that the negative perception of cats reduced and that the behavior of independent cats is in harmony with modern life patterns. Sales of dry feed for domestic cats are growing by 20% annually and the sales of wet feed market for domestic cats are growing by more than 30% every year for five years from 2010 to 2015.

1.2 Nutrient requirement for *Felis catus*

Recommendations relative to ME compared with relative to DM

Nutrient recommendations for cats are best expressed relative to ME rather than relative to DM because ME determines the amount of food that must be consumed by a cat to maintain BW and body condition score. Requirements expressed relative to ME do not change as the energy density of a diet changes, wheras requirements relative to DM vary with energy density of the food. For some nutrients, requirements have been established experimentally relative to DM rather than ME. These have been converted to requirements expressed relative to ME, at an energy density of 4,000kcal ME/kg. Following this conversion, it is the requirements and allowances expressed relative to ME, not those expressed relative to DM, that remain constant as the energy density of the diet changes.

For example, a cat maintaining its BW while consuming 240kcal ME would have to eat 60g DM of a food that contains 4,000kcal ME/kg DM but would have to consume 80g of a food containing only 3,000kcal ME/kg. In this example, a nutrient that must be included at a minimum of 8g/kg DM in the first diet need only be included at a concentration of 6g/kg DM in the second, but the nutrient requirement relative to ME remains the same (2g per 1,000kcal ME in this example) in both diets.

Thus, when using the table of nutrient requirements for dogs and cats to determine how much nutrient should be included in the diet when the nutrient density of a diet is not 4,000kcal ME/kg, the value of the requirement relative to kg DM reported in the table should be multiplied by the energy density of the new diet (in kilocalories ME per kg) and divided by 4,000 (NRC, 2006).

Requirements relative to ME in the food compared with requirements relative to BW

There is little information about how nutrient requirements vary with BW. Many nutrient requirements vary, as do maintenance energy requirements, relative to metabolic BW (BW with an exponent of 0.75 in lean dogs and 0.67 in lean cats; Rucker and Steinberg, 2002; Rucker and Storms, 2002). Other requirements may vary directly with BW or with some other exponent (Rivers and Burger, 1989).

Recommendations for maintenance in the table of nutrient requirements (Table 1) of cats has been calculated by assuming a moderate-sized lean adult cat of 4kg BW (NRC, 2006).

Table 1. Daily metabolizable energy requirements for adult cats at maintenance [1](NRC, 2006)

Type	Metabolizable Energy Requirement
Domestic cats, lean	100 kcal × kg $BW^{0.67}$
Domestic cats, overweight	130 kcal × kg $BW^{0.4}$
Exotic cats	55-260 kcal × kg $BW^{0.75}$

[1]Requirements of individual cats may be over- or underestimated by more than 50%.

2. Grooming behavior

2.1. Grooming behavior in *Felis catus*

The various grooming behaviors are important to a normal healthy cat. The lack of these behaviors can indicate depression or ill health. Their absence may also signal the potential for ectoparasite infestation or secondary conditions.

2.1.1. Functions of grooming behavior

New born kittens depend on the dam for grooming, especially during the first few days of life. Her licking not only conditions their coast but also stimulates urination and defecation until the young are physically able to move to a special area to eliminate.

As the cat matures, grooming becomes increasingly significant, until up to 50% of the awake time, or 15% of a 24-hour period, is spent performing some type of this behavior (Hart, 1976; Panaman, 1981; Eckstein and Hart, 2000).

Grooming serves several purposes, with the most important probably being maintenance of healthy skin. Removal of loose hair is necessary to keep the coat unmatted and free from dander. Grooming is also important to minimize ectoparasite infestations. In a flea-infested environment, prevention of oral grooming will result in twice the number of fleas and a scratch grooming frequency seven times higher than in a control group (Eckstein and Hart, 1997).

In hot weather, as much as one third of the cat's evaporative cooling loses can be achieved by licking the skin and hair (Hart, 1976). Another function of grooming is that of an affiliative behavior between two cats. Last, it can relieve tension, as may occur after a reprimand from the owner, after an encounter with a very aggressive cat, or preceding a thunderstorm (Fox, 1974).

2.1.2. Types of grooming in cats

Each type of grooming has an appetitive and a consummatory phase. The former phase is made up of the orienting components that direct the animal's attention to the affected body surface. The consummatory phase completes the response and consists of the lick, bite, or scratch (Trulson and Randall, 1976). Normal tactile stimulation to the cat's body results in either grooming of the region, or more commonly, no response (Trulson and Randall, 1976).

Oral grooming

The cat grooms much of its body with its tongue or teeth.

Licking as a form of grooming usually appears near the beginning of the kitten's second week with attempts at licking the forepaw. Within a few days, the kitten is licking the rest of its body. The caudally directed, well-developed lingual papillae are particularly suited for this form of grooming. Oral grooming most often occurs after periods of rest or sleep (Eckstein and Hart, 2000). It also occurs after eating, when a cat spends considerable time grooming by licking, particularly around the oral area. Direct licking is useful from the caudal to the midcerval area of the body. To reach various areas, the cat can assume some very unusual positions. The anogenital area is groomed after mating and during normal grooming periods. Oral grooming will involve multiple body areas 91% of the time and typically progresses from cranial toward caudal (Eckstein and Hart, 2000). If a cat is prohibited from grooming for 72 hours, a 67% increase in oral grooming will be seen during the next 12 hours. The incisors are useful for pulling burrs and tangles out of the hair coat and are often used to clean between the toes.

Paw grooming

Areas that cannot be groomed directly by the mouth are cared for using either forepaws or hindpaws. Because the head and neck are so difficult to care for, problems are more numerous in these areas (Hart, 1976a). The common form of grooming that follows eating, which is second only to licking, is use of the forepaw as a washing tool. The paw is licked several times, and then its medial side is wiped across the neck, the back of the head and ears, and finally the face. Often the head and neck are moved to accommodate this action. After every few swipes the cat again licks its paw. The young kitten usually begins this forepaw-washing behavior before it is 4 weeks of age.

Scratching various parts of the body with a hindpaw begins about 18 days after birth. As in paw washing, the areas most often scratced are those that cannot be licked, particularly the neck and auricular areas. Scratch grooming is usually directed toward singly regions and usually occupies only about 2% of the amount of time devoted to oral grooming (Eckstein and Hart, 2000). If prevented from scratching itself for several days, a cat will show an increase of 200% in the amount of scratching during the first 12 hours it is permitted (Eckstein and Hart, 2000).

Mutual grooming

When two cats are together by mutual agreement, it is common for one to lick or rub against the other. Allogrooming involves one cat licking another. This type of mutual, or social, grooming usually involves the head and neck, the most difficult places for which to care. Females will groom other females and males, whereas males will groom only females (Barry and Crowell-Davis, 1999). Cats, including queens grooming their kittens, have been known to chew off another's tactile hairs during a mutual grooming session (Bryant, 1944; Ehrenlechner and Unshelm, 1997). Beginning at a few weeks of age, social behavior tends to reach a peak when the kitten is between 5 weeks and 4 months (West, 1974). After that time, the frequency the mutual grooming sessions decreases.

Allorubbing usually involves one cat rubbing its head against the head or body of another cat, although the entire body could be used, not just the head. Female cats will allorub males more than males show the behavior to females (Barry and Crowell-Davis. 1999). Females will also rub males more often than other females, to the point that in homes with only female cats, allorubbing is rarely to never observed (Barry and Crowell-Davis. 1999). It has also been noted that an individual cat may rub another disproportionately more or less than is expected at random (Crowell-Davis et al., 1997). It is theorized that mutual rubbing facilitates the regular exchange of body odors. This will familiarize cats with each other and gradually result in a group odor (Crowell-Davis et al., 1997).

Mutual grooming can be extended to humans by licking them and accepting their petting. Most cats patiently accept a prolonged session of caressing, probably because they have no built-in mechanism to limit it (Ewer, 1968). In nature, one cat spends only a limited amount of time grooming another cat, and the receiver becomes almost immobile. Humans often extend this grooming session well beyond the normal length of time, and the cat usually accommodates them by not moving.

Displacement grooming

When a cat is in a conflict or stressful situation, it may appear ready to react but instead suddenly stops and performs an act that is out of context with the situation at hand, such as licking a paw and rubbing it across its face. Those are displacement activities. Presumably, this behavior reduces anxiety. A queen with kittens may increase her grooming of the young or of her own perineal and mammary regions during stress. If reprimanded for some behavior, a cat will often react by walking a distance away, then grooming. Cats that roll over and accidentally slide off a table or chair also respond with a grooming session, usually after glancing around the room.

Neuroendocrine and grooming relationships

Central controls of grooming behavior are not completely understood but are related to the pontine area of the brain and may be the same as for locomotion (Deliagina et al., 1981).

Serotonin is the neurotransmitter currently receiving the most attention because it can be affected by several popular drugs. Serotonin has not been linked to normal grooming behavior (Jerone, 1992). It has been shown, however, that a cat’s chewing or licking behavior can activate serotonin (Jerone, 1992).

Thyroid hormones and glucocorticoids play a role in central control of grooming behavior, although the exact mechanism is uncertain. Thyroidectomized cats show the reduces tryptophan levels in the rostral colliculi, but the relationship between these two situations is not understood (Trulson and Randall, 1976).

Hallucinogenic drugs can produce dissociated grooming. The body is positioned properly, but licking, biting, or scratching either does not occur or is poorly directed (Jacobs et al., 1976).

Circadian rhythms are difficult to identify, but studies of fragmented grooming behaviors have provided evidence that such cycles exist in the cat. Body temperature, caloric intake, and abnormal grooming activity fluctuate in 3- to 4-month periods, peaking in October or November and in June, and ebbing between February and may and in August (Randall and Parsons, 1969; Rogers et al., 1971; Trulson and Randall, 1973; Trulson et al., 1975; Trulson, 1976a; Trulson and Randall, 1976).

Hormone levels affect hair coat. Castrated males show a significant tendency toward longer hair (Searle, 1949). Queening, extended lactation, or both may result in hair loss, producing a thinner or shorter coat.

3. Hairball of domestic cats

3.1. Hairball formation in domestic cats

Daily hygiene routine of grooming in cats results in the formation of hairballs, or trichobezoars when the animals lick and ingest their own hair (Loureiro et al., 2014). The ingested hair is moved through stomach and intestines by peristalsis and hair becomes entangled into a solid mass (Debakey and Ochsner, 1938). Specifically, it has been reported that feline hairball formation may be associated with reduced intestinal motility occurring during prolonged fasting (De Vos, 1993) and with long-haired cats or cats that display frequent grooming and swallowing of hair (Ryan and Wolfer, 1978). Usually ingested hair is eliminated in feces but large quantities can accumulate in the digestive tract forming trichobezoars (or hairballs) that can cause digestive problem (Weber et al., 2015).

3.1.1. Physiology of hairball formation

Hairball formation in cats is generally considered to arise as a result of the routine activity of grooming where cats ingest varying quantities of hair. Single strands of ingested hair cannot be moved by peristalsis, thus become enmeshed in the gastric mucosa, eventually conglomerating into solid masses in either the stomach or intestine (DeBakey and Ochsner, 1938). Cats can generally rid themselves of this problem by retching until the hairball is vomited. Occasionally the aggregated ball of hair can accumulate to such an extent that a potentially serious obsturction can occur. Clinical signs of hairballs include vomiting, anorexia, and abdominal pain (Krugnet-Higby et al., 1996; Ryan and Wolfer, 1978; Krol et al., 2001).

Cat hairball formation is associated with a lack of intestinal motility during periods of fasting (De Vos, 1993), long hair, and consumption of hair from grooming (Ryan and Wolfer, 1978).

3.1.2. Feed for preventing hairball

The normal grooming activity in cats leads to hair ingestion. Together with the digesta, the swallowed hair can be moved by peristalsis and subsequently be voided with the feces (Malik, 2003). Cats get rid of gastric hairballs through retching until vomiting from the stomach or by passing them into the intestinal tract followed by excretion with the feces (Malik, 2003; Beynen et al., 2011).

It is believed that dietary fiber might reduce formation of trichobezoars (hairballs). Several scientific publications have either recommended or tested the use of additional dietary fiber (roughage) in the diet of animals that suffer from hairballs (Wagner et al., 1974; Leary et al., 1984; Mulder et al., 1992; Krugner-Higby et al., 1996). Traditional sources of dietary fibers used in pet foods include beet pulp and cellulose (Codoy et al., 2013). Beet pulp contains both insoluble and soluble fiber components in a desirable ratio. Cellulose is composed of insoluble and poorly fermentable fiber (De Godoy et al., 2013).

According to Beynen et al. (2011), feeding a diet with added cellulose lowers the frequency of hairball symptoms in cats. The diet fortified with cellulose lowered the incidence of vomiting, retching and coughing by 79, 91 and 70%, repectively, when compared with the control diet. The cellulose-induced decrease in vomiting was statistically significant.

The mechanism by which the ingestion of cellulose depresses the clinical signs of hairballs in cats is not known. In dogs, it has been shown that the feeding of cellulose reduces gastric emptying (Malagelada *et al.*, 1980) and enhances the intestinal transit rate of digesta (Burrows *et al.*, 1982). It could be suggested that delayed gastric emptying leads to binding of single strands of hair to food particles so that more hair is transferred into the duodenum and gastric hairballs are less easily formed. The cellulose-induced increase in transit rate of digesta may further promote the excretion of hairs with the feces (Beynen et al., 2011).

3.2. Chemical composition of hair

Hair threads form a major part of the external coating of most mammals. The hair thread is a natural fiber formed by keratin, a protein containing high concentration of sulfur coming from the amino acid cystine. Keratin is a laminated complex formed by different structures, which gives the hair strength, flexibility, durability, and functionality (Velasco et al., 2009).

Human hair has about 65-95% of its weight in proteins, more 32% of water, lipid pigments and other components. Chemically, about 80% of human hair is formed by a protein known as keratin (Kaplin et al., 1982; Wagner and Joekes, 2007), with a high grade of sulfur (coming from the amino acid cystine) which is the characteristic to distinguish it from other proteins. According to Harkey (1992), human hair (depending on its moisture content) consists of approximately 65-95% protein, 15-35% water and 1-9% lipids. The mineral content of hair is from 0.25-0.95% (on a dry weight basis). Human hair contains relatively large amount of glycine, threonine, aspartic and glutamic acid, lysine, cysteine and tyrosine (Robbins, 1988).

According to Hendriks (1998a), cat (*Felis catus*) hair was determined by conventional 24-h acid hydrolysis and calculated that crude protein make up approximately 67% and amino acids make up 0.86% of the total weight of cat hair. The most abundant amino acids in cat hair protein are cysteine, serine, glutamic acid, and glycine while only small amounts of methionine and histidine were found. The amino acid composition of hair protein is similar between the cat (*Felis catus*), dog (*Canis familiaris*), horse (*Equus caballus*), sheep (*Ovis aries*) and human (*Homo sapiens*) although it is notable that the proline content of cat hair appears to be lower than the other species.

Using the relative weight of the nitrogen in the individual amino acids, it can be calculated that the average proportion of amino acid nitrogen in cat hair protein is 0.175. Therefore, to calculate the protein content from the total nitrogen content of cat hair, a conversion factor of 5.78 should be used instead of the commonly used factor of 6.25 for protein or the factor of 6.37 for milk protein (Kirchgessner et al, 1967). The lower conversion factor for cat hair is mainly due to the relatively high concentrations of arginine, histidine and lysine present in this type of protein, which contain four, three and two atoms of nitrogen, respectively (Hendriks, 1998a).

4. Apparent digestibility trial in cats

4.1. Adaptation period of apparent digestibility trial in cats

According to the Association of American Feed Control Officials (AAFCO), the recommendations for standard protocols for measuring the apparent digestibility of diets for cats and dogs were published (AAFCO, 1993; Nott et al., 1994). The protocol recommends a 5d precollection or adaptation period followed by a 5d period of feces collection for both species. However, the domestic cat is an obligate carnivore, whereas the dog has adapted to a more varied diet, and it seemed likely that the dog might be more adaptable to a varying diet

(Nott et al., 1994). So, according to Nott et al. (1994), there was no significant differences between the different collection periods in apparent digestibility of dogs, but the protein digestibility of cats was significantly lower when collecting the feces in long period (15-21d) than in short period (8-14d). During the collection over 4-7d, the cats produced quite dry feces, and this had stabilized to typical levels during the last collection (15-21d). According to the result of Nott et al. (1994), 4d collection period following a 3d adaptation is sufficient to measure apparent digestibilities in dogs, however, this short period of collection was insufficient to enable full fecal analysis in cats, and cats might require a longer adaptation period than dogs if accurate digestibilites are to be measured. According to Edney (1988), to measure availability of nutrients of cats, feeding for 3wk is recommended in cats. So Funaba et al. (2002) took 14d for adaptation period and 7d for collection period. According to the recent studies, Kerr et al. (2012) and Kerr et al. (2014), the experimental cats were adapted to dietary treatments for 16d before a 5d collection period. Therefore, we conducted the present study following the 16d of adaptation period of Kerr et al. (2014).

4.2. Sample collection of apparent digestibility trial in cats

It is well known that the domestic cats swallowed their own hair as a result of daily routine of grooming (DeBakey and Ocjsner, 1938). The barbs on a cat’s tongue encourage ingestion of fur when grooming (Cannon, 2013). According to Panaman (1981), the time spent grooming accounted for around 25% of the cat's waking hours. Therefore, it is not surprising that cats ingest large amounts of hair every day, most of that passes through the gastrointestinal tract and is expelled as undigested hair within the feces (Panaman, 1981; Cannon, 2013). And also, according to Weber et al. (2015), usually ingested hair is eliminated in feces.

According to Hendriks (1998b), the amount of hair found in the feces was 25-75mg/kg body weight per day. And Lourciro et al (2014) supposed that the amount of hair found in feces were approximately 87-143mg per cat per day and 4.7-11mg/g feces DM. These studies proved the fact that the large amount of hair normally present in the feces of the cats. Although the hair within the feces may influence the determination of nutrient digestibility in domestic cats, there was no detailed study about how to handle the hair in the feces samples when conducting the apparent nutrient digestibility trials.

For example, according to De-Oliveira et al (2008), fecal output samples were frozen (-15℃) as they were collected during the collection period. And at the end of the collection period, feces were thawed, homogenized, and pooled by cat. Before performing laboratory tests, feces were dried in a forced-air oven at 55℃ for 72h and ground in a cutting mill with a 1-mm sieve. Fecal samples must had contained hair, but there was no mention about the presence of hair in feces samples when analyzing for nutrient digestibility in De-Oliveira et al (2008). And also, there was no mention about handling the hair within the feces samples when conducting the apparent nutrient digestibility trials in other studies (Funaba et al., 2005; Kerr et al., 2012; Kerr et al., 2014).

Ⅲ. Effect of Cats' Grooming Behavior on Apparent Digestibility in Domestic Cats

Abstract

This experiment was conducted to evaluate the time budget and organization of grooming both in short-haired and long- haired cats. And the other purpose of this experiment was to assess the effect of grooming behavior of cats on apparent digestibility in domestic cats (*Felis catus*) by comparing the apparent digestibility of domestic cats using hair-included-feces and hair-removed-feces. A total of 10 adult domestic cats, averaging 4.3±0.89 kg body weight and average 3.5±1.38 year, were used for behavioral observation. There was no significant difference between long-haired and short-haired cats in behavioral time budget and organization of grooming. A total of 14 adult domestic cats, averaging 4.5±1.21 kg body weight and 3.3±1.38 year, were used for nutrient digestibility trial. The treatments of digestibility experiment were HI; hair-included -digestibility and HR; hair-removed-digestibility. The apparent nutrient digestibility in hair-removed-feces treatment was higher than that of hair-included-feces treatment. Therefore, the digestibility of dry matter, crude protein, crude ash, ADF and NDF has been underestimated approximately 6%, 7%, 15%, 12% and 10%, respectively when it was calculated using conventional digestibility method for domestic cats. The nutrient digestibility between long-haired and short-haired cats had no difference when hair-included-feces was used. However when using hair-removed-feces, the digestibility of NDF and amino acid in long-haired cats were higher than that of short-haired cats about 4-8% ($P<0.05$). Therefore, the presence of hair in the fecal samples should be considered before calculating the apparent nutrient digestibility of domestic cats (*Felis catus*).

Key words : Apparent nutrient digestibility; Behavioral observation; Domestic cats; Grooming behavior; Hair included in feces

Introduction

Small felids, including domestic cats are known for frequent grooming (Eckstein and Hart, 2000). Cats are engaging in paw licking and face washing as well as licking the pelage. Since cats typically draw the keratinous cornified papillae of the tongue over the surface of the pelage, a large amount of hair is ingested while licking (Eckstein and Hart, 2000; Weber et al., 2015).

Grooming serves several purposes such as removal of lost hair to keep the coat unmatted and free from dander to maintain healthy skin. Grooming removes ectoparasites (Hart, 1990; Hart, 1997), it also removes dirt and stale oil, maintaining insulating capacity of the pelage and temperature control (Eckstein and Hart, 2000).

A cat can spend approximately 25% to 30% of its time on grooming (Hart, 1976b; Panaman, 1981). Some cats have been observed to spend up to one-third of their awake time for grooming (Loureiro et al., 2014) and domestic cats spent about 50% of the time budget sleeping and resting (Eckstein and Hart, 2000). Oral and scratch grooming accounted for 4% and 0.1%, respectively of the overall time budget or 8% and 0.2%, respectively of non-sleeping resting time when grooming was possible. The most oral grooming was done around head as the form of face washing 31%, followed by the hindleg licking 21%, sides-back 13%, neck-chest 11%, anogenital 10%, abdomen 9% and tail 5% (Eckstein and Hart, 2000)

Daily hygiene routine of grooming in cats results in the formation of hairballs, or trichobezoars when the animals lick and ingest their own hair (Loureiro et al., 2014). The ingested hair is moved through stomach and intestines by peristalsis and hair became entangled into a solid mass (Debakey and Ochsner, 1938). Specifically, it has been reported that feline hairball formation may be associated with long-haired cats or cats that display frequent grooming and swallowing of hair (Ryan and Wolfer, 1978). Usually ingested hair is eliminated in feces but large quantities can accumulate in the digestive tract forming trichobezoars (or hairballs) that can cause digestive problem (Weber et al., 2015).

According to Harkey (1993), human hair (depending on its moisture content) consists of approximately 65-95% protein, 15-35% water, and 1-9% lipids. Cat (*Felis catus*) hair was determined by conventional 24-h acid hydrolysis and calculated that crude protein make up approximately 67% and amino acids make up 0.86% of the total weight of cat hair (Hendriks, 1998a). The amount of hair found in the feces was 25-75mg/kg body weight per day (Hendriks, 1998b). The trichobezoars in feces were approximately 87-143mg per cat per day and 4.7-11mg/g feces DM (Lourciro et al., 2014). Therefore, the large amount of hair normally present in the feces of the cat may influence the determination of nutrient digestibility in domestic cats. As hair has been shown to mainly consist of amino acids (Hendriks et al., 1998a), the digestibility of amino acids may be also underestimated. This may be particularly significant for the amino acid cysteine, because cysteine was found in high concentrations in cat hair (Hendriks et al., 1998).

Information on 24hour time budgets for quantitative behaviour assessments of single caged cats is surprisingly limited. Carlstead et al. (1993) reported information on durations spent alert/awake and in exploratory/play behaviour. However, other reports (De Monte and Le Pape, 1997, Kry and Casey, 2007, Ellis and Wells, 2010) are based upon limited observations during only part of a 24-hour day. There have been a number of sleep studies of cats in single cages that have shown that cats can sleep for 48-55 percent, are drowsy for 14-28 percent, and alert and active for 18-33 percent of a 24-hour day (Lancel et al., 1991; Ellis et al., 2014).

The aim of the current study was to use simultaneous measurements of quantitative and qualitative behaviour to provide a 24-hour time budget for grooming in short-haired-cats and long-haired-cats. The other purpose of this study was to assess the effect of grooming behavior of cats on apparent digestibility in domestic cats (*Felis catus*) by examining the time budget for grooming in short-haired and long-haired cats and comparing the apparent digestibility of domestic cats using hair-included-feces and hair-removed-feces.

Materials and Methods

All animal procedures were approved by IACUC of Seoul

National University (SNUIACUC-160712-22) before animal experiment. The present study was proceeded according to guidelines provided in SNUIACUC.

Experiment 1: Time budget and organization of grooming (Behavioral observation)

Animal

Total ten adult domestic cats (*Felis catus*; five long-haired cats and five short-haired cats; average age : 3.5±1.38year; average body weight : 4.3±0.89kg) were used to conduct this study. In total five females and five males, all of which were spayed or neutered, were used. Good health status was confirmed prior to beginning the study by veterinarians working in Irion animal hospital.

Housing and management

Cats were housed individually in stainless-steel cages (0.77 × 0.51 × 0.63m) at the Irion animal hospital (445, Dosan-daero, Gangnam-gu, Seoul, Republic of Korea) in a constant temperature (22-23℃). Because videotaping was used to record behaviour for detailed analysis, it was necessary for each cat to be placed alone in an observation cage. Within each cage, there was a shelf (0.51 × 0.29m) elevated (0.3m) off the floor, a litter box (0.33 × 0.44 × 0.16m), and water dishes secured to the cage door (Figure 1). Starting at 06:00, 14hours of fluorescent light was provided followed by 10hours of darkness, supplemented with light infrared lighting by recording web cam. The subjects were in visual, auditory, and olfactory contact with the other cats of the colony.

All cats remained healthy throughout the study and no signs of ectoparasitism. The cats were offered individually calculated amounts of dry extruded diet (chicken based grain-free commercial feed, provided by Daehanfeed company, Republic of Korea). The amount was defined according to the energy requirements for adult cat maintenance, estimated as $ME = 100 \times BW^{0.67}$ (NRC, 2006). Food was provided twice daily (at 09:00 and 16:00h). Water was provided *ad libitum*. Litter boxes were cleaned between 08:00 and 09:00h, and between 15:00 and 16:00h.

Continuous quantitative behavioral observations

The cats' behaviour was recorded on a web-cam videotaping system for one 24hour period following an initial 12h habituation period. The subjects were continuously video recorded using web-cam (Xiaoyi smart web-cam®, Shanghai Xiaoyi Technology Co, China) and micro SD card (Micro SDHC EVO 32GB, Samsung, korea) for 36 hours. The behavioral recordings were viewed at 1.5 times the actual speed by two observers.

Analysis of cats' behaviour

Scoring of behaviour was based on an ethogram of mutually exclusive behavioral categories appropriate to a solitary-caged cat (Table 1). The duration of time spent in each behavioral category was recorded in sequence. The category of "sleep/rest" included what appeared to be unconscious sleep as well as conscious, but quiet rest.

Because it was not always possible to distinguish between sleep and rest, these two behavioral states were treated as one category. In either case, the animal was in a posture in which very limited grooming, if any, was possible. The category of 'general activity' included moving about the cage and sitting where grooming could easily occur.

Grooming was noted as either oral or scratch grooming, and the anatomical area(s) groomed were recorded. A grooming bout was considered terminated when a non-grooming activity occurred (e.g., eating, eliminating, rest), or if more than 60s elapsed without a licking episode. Cats were seen sometimes to deliver several licks, pause for a few seconds without engaging in any other identifiable behaviour, and then continue licking; this was not considered a new grooming bout. However, in order to improve recording accuracy of cumulative grooming time within prolonged grooming bouts, separate start and stop times were entered if more than 5s of non-grooming followed a grooming episode within a grooming bout. These separate entries were then summated to derive the duration of the bout. For oral grooming, no distinction was made between incisor nibbling or tongue-stroking when grooming was directed to a single region. The anatomical regions for oral grooming were: head (face washing), neck and chest, sides and back, abdomen, hindlegs, anogenital area and tail (Table 2). For scratch grooming, the anatomical regions were chin (including head rostral to the ears), ear and neck. In preliminary trials, a greater than 90% inter-observer reliability was established for the two individuals scoring the videotapes.

Data analysis

The time budget analysis was derived from data pooled from all cats, and tabulated as a percentage of total observation time. Because each subject was observed for the same amount of time, data from each individual animal contributed equally to the data set.

Statistical analysis

The experimental data was analyzed using Student's *t*-test procedure of SAS (SAS Institute, 2009), and a main effect in the statistical model was the length of cat's hair. Individual cats were used as a unit to analyze behavioral observation. Differences were determined using a Fisher's protected LSD. A probability of $P<0.05$ was accepted as statistically significant and highly significant at $P<0.01$. Reported pooled SEM were determined according to the Student's *t*-test procedure of SAS.

Experiment 2: Effects of grooming on apparent digestibility trial in domestic cats (*Felis catus*)

Animal

Fourteen adult domestic cats (*Felis catus*; six long-haired cats and eight short-haired cats; average age : 3.3±1.38year; average body weight : 4.5±1.21kg) were used to conduct the study. In total seven females and seven males, all of which were spayed or neutered, were used. The experimental cats consist of six long-haired cats (*Persian*) and eight short-haired cats (*Domestic Short Hair*). Good health status was confirmed prior to beginning the study by veterinarians working in Irion animal hospital.

Experimental design

The treatments were: 1) HI; hair-included-digestibility, 2) HR; hair-removed-digestibility. Experimental period was 26d included an adaptation phase (d 0 to 16), followed consecutively by a fecal collection phase (d 17 to 26). Fecal collection phase (d 17 to 26) was composed of two period, one (d 17 to 21) for analyzing hair-included-digestibility samples and the other (d 22 to 26) for analyzing hair-removed-digestibility samples.

Housing and management

Cats were housed individually in stainless-steel cages (0.78 × 0.54 × 0.62m) at the Irion animal hospital (445, Dosan-daero, Gangnam-gu, Seoul, Republic of Korea) light-controlled (14h light: 10h dark) room. The room was maintained at a constant temperature of 22-23℃. Within each cage, there was a shelf (0.51 × 0. 29m) elevated (0.3m) off the floor, a litter box (0.33 × 0.44 × 0.16m), and water dishes secured to the cage door (Figure 2). All cats remained healthy throughout the study, based on physical examination. Litter boxes were cleaned between 08:00 and 09:00h, and between 15:00 and 16:00h. Each day, food was weighted and divided into 2 equal porportions, placed in stainless steel bowls, and left out at 09:00 and 16:00h. Bowls were removed before the next meal, and any remaining food was weighted and recorded. Water was provided *ad libitum*.

Diets

The cats were offered individually calculated amounts of dry extruded diet (chicken based grain-free commercial feed with 2% of refined cellulose and 3% of sugar beet pulp for hairball prevention, provided by Daehanfeed company, Republic of Korea). Initially, the amount was defined according to the energy requirements for adult cat maintenance, estimated as $ME = 100 \times BW^{0.67}$ (NRC, 2006). Food was provided twice daily (at 09:00 and 16:00h). Water was provided *ad libitum*. Cats were adapted to dietary treatments for 16 d before a 10-d collection period. During the collection period, food offered, refused and fecal output were measured daily and used for digestibility. All food consumptions were measured out using electronic scales (WZ-3A, CAS, Zhongshan Hengxin, China) accurate to within 0.1g. The analyzed chemical composition of the experimental diet were presented in Table 3 and Table 4.

Sample collection

On the first day of fecal collection, all feces was removed from the cages and discarded before 09:00h. Fecal output was collected from this time on for the next 10d (5d for hair-removed-feces samples and 5 d for hair-included-feces samples). During the collection phase, total fecal outputs were collected. To ensure complete collection, cats were acclimated to a multi-tier litter box with no litter, which allowed urine flow to the bottom and feces to remain on the top. Fresh fecal samples (within 15min of defecation) were obtained during the collection phase.

Fresh fecal samples were weighed and stored at –20℃ until further analysis. Total feces were collected, composited, dried at 55℃ in a drying oven (AMP Daw Model 18, Daihan scientific, Korea) and ground through a 1-mm screen (Wiley Mill intermediate, Thomas Scientific) for hair-included-feces samples.

To compare the apparent digestibility of domestic cats using hair-included-feces and hair-removed-feces, we were unable to find published studies that removed hair in cat feces. Thus we developed the following protocol based on our observations of cat faecal traits. As collecting the hair-included-feces samples, we collected fresh total faecal output and dried at 55℃ in a drying oven (AMP Daw Model 18, Daihan scientific, Korea). We took out all the hair using pincette and then ground through a 1-mm screen (Wiley Mill intermediate, Thomas Scientific) for hair-removed-feces samples .

Hairball (trichobezoar) quantification in cat feces (pre-test)

Faecal hair excretion was quantified according to the method of Lourciro et al. (2014). Stored, frozen feces samples were washed with tap water over a sieve with 0.8mm screen size and gently washed until all faecal material was removed and only hair remained. The remaining hair was collected and dried in a forces air oven at 55℃ for 24h (AMP Daw Model 18, Daihan scientific, Korea), and washed in a 1:1 (v/v) solution of diethyl ether and petroleum diethyl ether until all foreign materials were removed from the sample. The isolated hair samples were weighed and classified according to the length of cats' hair; short-haired cats or long-haired cats. The samples were presented in Figure 3 and pooled hairball samples for chemical analysis were presented in Figure 4. The analyzed values of chemical composition of cats' hairball was presented in Table 5. The average weight ratio of dried feces samples and the hair isolated from feces were presented in Table 6.

Chemical analyses

Experimental diet, hairball samples and excreta samples (hair-included-feces and hair-removed-feces) were analyzed for contents of dry matter (procedure 930.15; AOAC, 1995), ash (procedure 942.05; AOAC, 1995), ether extract (procedure 920.39; AOAC, 1995), N by using the Kjeldahl procedure with Kjeltec (KjeltecTM 2200, Foss Tecator, Sweden). Experimental diet and excreta samples were analyzed for contents of CP content (nitrogen × 6.25; procedure 988.05; AOAC, 1995), but hairball samples were analyzed for contents of CP content (nitrogen × 5.78; Hendriks, 1998b). The experimental diet and feces samples were analyzed for amino acid composition by using 2-Ninhydrin procedure with Hitach L-8900 (Beckman Instruments Corp, Palo Alto, CA). Calcium and total phosphorus of samples were analyzed by ICP-OES (Icap-7400Duo, Thermo scientific, China). NDF and ADF of samples were analyzed by Fiber Anlyzer A2000 (ANKOM A2000, ANKOM Technology, USA).

Statistical analysis

The experimental data was analyzed using Student's *t*-test procedure of SAS (SAS Institute, 2009), and a main effect in the statistical model was the length of cat's hair. Individual cats were used as a unit to analyze nutrient digestibility. Differences were determined using a Fisher's protected LSD. A probability of $P<0.05$ was accepted as statistically significant and highly significant at $P<0.01$. Reported pooled SEM were determined according to the Student's *t*-test procedure of SAS.

Results and Discussion

All cats consumed adequate amount of the diets, and BW did not change during the whole experiment period.

Experiment 1: Time budget and organization of grooming (Behavioral observation)

Behavioral observation

The time budget for ethogram of mutually exclusive behavioral categories (total 24hours) was presented in Table 7. According to previous study (Eckstein and Hart, 2000), domestic cats spent 50% of the time budget sleeping and resting. According to other studies (Lancel et al., 1991; Ellis et al., 2014), cats could sleep for 48-55 percent and were drowsy for 14-28 percent of a 24hour day. In the present study, experimental cats spent 69-71 percent of a total 24hours sleeping and resting. There was no significant difference between long-haired cats and short-haired cats in sleeping and resting.

According to Eckstein and Hart (2000), oral and scratch grooming accounted for 4% and 0.1% of the overall time budget. In present study, oral and scratch grooming accounted for 2% and 0.2% respectively of the full-time budget. Time budget for oral grooming and scratch grooming of long-haired cats were numerically higher than short-haired cats, but there was no significant difference between them. There was no significant difference between long-haired and short-haired cats in other behavioral time budget.

The time budget for anatomical areas of grooming was presented in Table 8. As calculated the overall grooming time as 100%, the time budget for oral grooming of total experimental cats was 92% and scratch grooming was 8% respectively in present study. In the present study, the region receiving the most oral grooming was the head in the form of face washing 52%, followed by the side-back licking 14%, hindleg 9%, neck-chest 8%, anogenital 3%, tail 3% and abdomen 3%. According to Eckstein and Hart (2000), the region receiving the most oral grooming was face washing 31% as recorded same ranking in this experiment. However, hindleg licking was in second place recording 21% and followed by side-back 13%, neck-chest 11%, anogenital 10%, abdomen 9% and tail 5% of total time budget in the previous study. Because of the difference of species and ages of the experimental animals might derive the change of the grooming ranking between the previous study (Eckstein and Hart 2000) and present study. There was no significant between long-haired cats and short-haired cats in grooming patterns in present study.

Experiment 2: Effects of grooming on apparent digestibility trial in domestic cats (*Felis catus*)

Hair-included vs hair-removed in cats

The apparent nutrient digestibility and apparent amino acid digestibility using hair-included-feces and hair-removed-feces were represented in Table 9 and Table 10, respectively. There were no significant differences between two treatments in nutrient digestibility of crude fat, Ca and total P. However, the digestibility of dry matter, crude protein, crude ash, ADF and NDF of hair-removed treatment were significantly higher than those of hair-included treatment about 6%, 7%, 14%, 12% and 10%, respectively ($P<0.01$, $P<0.01$, $P<0.01$, $P=0.01$, $P<0.01$). According to the analyzed moisture value of cats' hairball isolated from feces (Table 5), it was 5.67% which was higher than moisture value of cats' feces samples (2.1-4.5%). And in Table 7, the ratio of the hair isolated from feces and dried feces were 7.4-9.8%. Hendriks (1998b) announced that the amount of hair found in the feces was 25-75mg/kg body weight of cat/day. According to Lourciro et al. (2014), hairballs isolated from the feces of cats were 87-143mg/cat/day. The moisture composition of hair in the feces might influence the DM value of feces sample, so the nutrient digestibility values became changed. So if we use the conventional method to calculate the cats' apparent nutrient digestibility the way that using hair-included-feces samples, the digestibility of dry matter, crude protein, crude ash, ADF and NDF would be underestimated about 6%, 7%, 14%, 12% and 10%, respectively.

The apparent amino acid digestibility such as ASP, SER and GLY of hair-removed treatment showed higher value than hair-included treatment about 6%, 6% and 3%, respectively ($P=0.04$, $P=0.02$, $P=0.02$). Especially, CYS digestibility of hair-removed treatment was significantly higher than that of hair-included treatment about 20% ($P<0.01$). According to Hendriks (1998a), cats' hair has been shown to mainly consist of amino acids, and the composition of CYS was the highest (15.8%) among the other amino acid composition. As Hendriks (1998a) supposed, the digestibility of crude protein and amino acids were revealed to be truly underestimated in the present study, if we use the conventional apparent digestibility method which is using hair-included-feces samples to calculate the cats' nutrient digestibility.

Hair-included vs hair-removed in long-haired cats

The apparent nutrient digestibility and apparent amino acid digestibility of long-haired cats using hair-included-feces and hair-removed-feces were presented in Table 11 and Table 12, respectively. There were no significant differences between two treatments in nutrient digestibility of crude fat, crude ash, ADF, Ca and total P in long-haired cats. However, the digestibility of dry matter, crude protein and NDF of long-haired cats was underestimated when calculated using hair-included-feces about 8%, 9% and 14%, respectively (P=0.02, P=0.04, P=0.04).

According to Table 6, the average weight ratio of dried feces samples and the hair isolated from feces (total 5 days) of long-haired cats was 9.69%, which is higher than that of short-haired cats (7.43%). As mentioned above, because of the moisture value (5.67%) of cats' hairball which was included in the feces, the digestibility of dry matter of hair-included treatment was underestimated. And in Table 5, the analyzed value of crude protein of cats' hairball isolated from feces was 58.93%. According to Hendriks (1998a), crude protein of cat hair was 62.15%. So, the digestibility of crude protein of hair-removed treatment was higher than that of hair-included treatment. According to Beynen et al. (2011), feeding of a diet with added cellulose decreased the frequency of hairball vomiting statistically significant. Fibers may cause greater peristaltic stimulation, increasing the propulsion of hair through the gut, but further research is needed to validate this mechanism (Lourciro et al., 2014). In the present study, we used experimental diet with 2% of refined cellulose and 3% of sugar beet pulp for hairball prevention. Cellulose was belong to NDF and sugar beet pulp was composed of 36.25% NDF and 21.58% ADF (Doosan feed company, Korea). Therefore, NDF digestibility would have been affected by the presence of hair in feces samples, but further research is needed to validate this result.

The apparent amino acid digestibility such as total amino acid, ASP, THR, SER, GLU, GLY, ALA and CYS of hair-removed treatment showed higher value than hair-included treatment about 9%, 12%, 11%, 12%, 8%, 7%, 8% and 33%, respectively (P=0.04, P=0.03, P=0.04, P=0.03, P=0.04, P=0.02, P=0.04, P=0.02). According to Hendriks (1998a), cat hair had shown to mainly consist of protein and amino acids. In the present study, the digestibility of amino acids were revealed to be truly underestimated about 7-33% in long-haired cats, if we use the conventional apparent digestibility method which is using hair-included-feces samples to calculate the cats' nutrient digestibility.

Hair-included vs hair-removed in short-haired cats

The apparent nutrient digestibility and apparent amino acid digestibility of short-haired cats using hair-included-feces and hair-removed-feces were shown in Table 13 and Table 14, respectively. The digestibility of dry matter, crude protein and crude ash when using hair-removed samples for calculation were higher than using hair-included samples in short-haired cats about 4%, 5% and 15%, respectively (P=0.01, P=0.02, P<0.01). So it can be assumed that the digestibility of dry matter, crude protein and crude ash of short-haired cats were underestimated about 4%, 5% and 15%, respectively, when calculated using hair-included-feces.

There were no significant differences between two treatments in amino acid digestibility in short-haired cats. According to Table 6, the average weight ratio of dried feces samples and the hair isolated from feces (total 5 days) of short-haired cats was 7.43%, which is lower than that of long-haired cats (9.69%). Because there was less amount of hair in the feces samples in short-haired cats than long-haired cats, the presence of hairballs in the feces did not show significant effect on amino acid digestibility.

Short-haired cats vs long-haired cats using hair-included feces

Comparing apparent nutrient digestibility and apparent amino acid digestibility of long-haired cats and short-haired cats using hair-included-feces were represented in Table 15 and Table 16, respectively. There were no significant differences between two treatments in nutrient digestibility and amino acid digestibility when using hair-included-feces. Even the length of the hair was different, both experimental cats were in same kind of domestic cats, the nutrient digestibility did not show significant difference when using the conventional digestibility trial.

Short-haired cats vs long-haired cats using hair-removed feces

Comparing apparent nutrient digestibility and apparent amino acid digestibility of long-haired cats and short-haired cats using hair-removed-feces were shown in Table 17 and Table 18, respectively. There were no significant differences between two treatments in nutrient digestibility of dry matter, crude protein, crude fat, crude ash, crude fat, ADF, Ca and total P. However, NDF digestibility of long-haired cats were 4% higher than that of short-haired cats (P=0.03). As mentioned above, more amount of hair was found in the feces of long-haired cats than short-haired cats, it could be assumed that the presence of hair in the feces samples had more effect on nutrient digestibility of long-haired cats than that of short-haired cats. As Lourciro et al. supposed (2014), fibers helped the hair to be excreted with the feces. In the present study, using experimental diet with 2% of refined cellulose and 3% of sugar beet pulp for hairball prevention, NDF digestibility had been affected by the present of hair in feces samples. So, the NDF digestibility of long-haired cats increased higher than that of short-haired cats when eliminated the hair in the feces to calculate the apparent digestibility.

The amino acid digestibility of total amino acid, ASP, THR, SER, GLU, GLY, ALA, LEU and ARG of long-haired cats were higher than those of short-haired cats when using hair-removed-feces about 6%, 8%, 8%, 7%, 6%, 5%, 6%, 7% and 5% (P=0.03, P=0.02, P=0.03, P=0.02, P=0.03, P=0.02, P=0.02, P=0.03, P=0.02). As mentioned above, the average weight ratio of dried feces samples and the hair isolated from feces of long-haired cats was higher than that of short-haired cats (Table 6). According to Hendriks (1998a), the total amino acid composition of cat hair protein was 58.72%, while the average value of total amino acid composition of cat feces was 19.82% in this study. Because of the difference of the distribution ratio of amino acid in feces and hair, and the hair content in feces samples between treatments, the long-haired cats showed higher amino acid digestibility than short-haired cats when using hair-removed-feces.

Conclusion

The ratio of the weight of hair isolated from feces and dried feces of long-haired cats was 9.79% which is higher than that of short-haired cats, 7.43%. However there was no significant difference between long-haired cats and short-haired cats in time budget of behavioral categories and grooming patterns.

The digestibility of dry matter, crude protein, crude ash, ADF, NDF, ASP, SER, GLY and CYS was underestimated about 6%, 7%, 14%, 12%, 10%, 6%, 6%, 3% and 20% respectively, when calculated using conventional digestibility method ($P<0.01$, $P<0.01$, $P<0.01$, $P=0.01$, $P<0.01$, $P=0.04$, $P=0.02$, $P=0.02$, $P<0.01$). Because of the chemical composition of hair included in feces, the nutrient digestibility using hair-removed-feces was higher than hair-included-feces. The nutrient digestibility between long-haired and short-haired cats had no difference when using hair-included-feces. However when using hair-removed-feces, the NDF and amino acid digestibility of long-haired cats were higher than short-haired cats about 4-8% ($P<0.05$). Therefore, the presence of hair in the feces samples should be considered before calculate the apparent nutrient digestibility of domestic cats (*Felis catus*). Further research will be needed to validate the mechanism of how fiber affects the propulsion of hair to find out how the presence of hair in the feces affects NDF digestibility in cats.

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Table 1. Ethogram of mutually exclusive behavioral categories (Eckstein and Hart, 2000)

Category	Description
General activity	Sitting (usually attending to environmental stimuli) or mobile (exploring, playing), while not engaged in another specific behaviour
Sleep/rest	In recumbence with minimal head and limb movements. Movement to re-position was included as continuous rest
Oral groom	Stroking the tongue through the skin or hair, or applying saliva to the head with the front limbs after licking them (face washing).
Scratch groom	Scratching the body with the hind claws
Eat	Eating from the food bowl and subsequent chewing
Drink	Drinking from the water bowl
Eliminate	Urination and defection, including subsequent raking of the litter box

Table 2. Anatomical areas of grooming (Eckstein and Hart, 2000)

Region	Anatomical details
Oral grooming	
Face(wash)	Front paws and legs; head
Neck/chest	The frontal plane including the chest and shoulders
Sides/back	The sides and back, caudal to the shoulders and cranial to the tail, groomed by lateral neck flexion
Abdomen	The ventral area caudal to the shoulders and cranial to the tail, groomed by ventral neck flexion
Hindleg	Hindlegs and feet
Anogenital	The genital, anal and perianal areas and proximal third of the ventral tail
Tail	Distal 2/3 of the tail
Scratch grooming	
Chin	The head rostral to the ears, including the chin
Ear	The head caudal to and including the ears
Neck	Caudal to the head and cranial to the shoulders

Table 3. Analyzed values of the experiment diet

Criteria (%)	Experimental diet[1]
Moisture	6.47
Crude protein	33.01
Crude ash	7.56
Crude fat	15.40
Calcium	1.33
Total phosphorus	0.89
Crude fiber	3.59
Acid detergent fiber (ADF)	11.52
Neutral detergent fiber (NDF)	33.98

[1]Provided by Daehanfeed company.

Table 4. Analyzed amino acid values of the experiment diet

Criteria (%)	Experimental diet[1]
Total amino acid	21.39
Aspartic acid (ASP)	1.99
Threonine (THR)	0.99
Serine (SER)	0.96
Glutamic acid (GLU)	2.94
Glycine (GLY)	1.97
Alanine (ALA)	1.56
Valine (VAL)	0.85
Isoleucine (ILE)	0.71
Leucine (LEU)	1.62
Tyrosine (TYR)	0.69
Phenylalanine (PHE)	0.83
Lysine (LYS)	1.68
Histidine (HIS)	0.58
Arginine (ARG)	1.54
Proline (PRO)	1.37
Methionine (MET)	0.82
Cysteine (CYS)	0.29

[1]Provided by Daehanfeed company.

Table 5. Analyzed values of chemical composition of cats' hairball isolated from feces

Criteria (%)	Cats' hairball isolated from feces
Moisture	5.67
Crude protein[1]	58.93
Crude ash	4.66
Crude fat	4.77
Calcium	1.20
Total phosphorus	0.69

[1]To calculate the protein content from the total nitrogen content of cat hair; a conversion factor of 5.78 should be used instead of the commonly used factor of 6.25 for protein or the factor of 6.37 for milk (Kirchgessner et al., 1967; Hendriks, 1998b)

Table 6. The average weight ratio of dried feces samples and the hair isolated from feces (total 5 days)

Criteria[1]	Dried feces (g)	Hair isolated from feces (g)	Ratio (%)
Long-haired cats	59.18	5.62	9.79
Short-haired cats	65.82	4.84	7.43

[1] A total of 14 domestic cats with an average age 3.3±1.38year.

Table 7. The time budget for ethogram of mutually exclusive behavioral categories (total 24hours)

Category (%)	Total[1]	Long-haired cats[2]	Short-haired cats[2]	SEM[3]	P-value
General activity	25.82	26.30	25.33	3.335	0.89
Sleep/rest	69.97	68.77	71.17	3.386	0.75
Oral groom	2.29	2.64	1.94	0.301	0.28
Scratch groom	0.18	0.24	0.12	0.047	0.26
Eat	0.89	0.99	0.79	0.076	0.21
Drink	0.48	0.59	0.36	0.127	0.42
Eliminate	0.39	0.48	0.30	0.116	0.46

[1] A total of 10 domestic cats with an average age 3.5±1.38 year.

[2] The number of observations for each mean value was five (n=5 for Long-haired cats and short-haired cats).

[3] Standard error of the mean.

Table 8. The time budget for anatomical areas of grooming[1]

Zone (%)	Total[2]	Long-haired cats[3]	Short-haired cats[3]	SEM[4]	P-value
Oral grooming	91.81	91.64	91.98	2.272	0.95
Face(wash)	52.13	50.67	53.59	3.962	0.74
Neck/chest	7.56	8.04	7.07	2.948	0.88
Sides/back	13.97	11.53	16.41	2.495	0.39
Abdomen	2.65	2.68	2.62	0.683	0.97
Hindleg	8.66	10.32	6.99	2.505	0.55
Anogenital	4.06	5.39	2.73	1.164	0.29
Tail	2.79	3.00	2.57	0.949	0.84
Scratch grooming	8.19	8.36	8.02	2.272	0.95
Chin	1.58	1.50	1.67	0.406	0.85
Ear	3.44	2.31	4.56	1.531	0.51
Neck	3.17	4.55	1.80	1.324	0.34

[1] Calculated values on the basis of grooming time as 100%.

[2] A total of 10 domestic cats with an average age 3.5±1.38 year.

[3] The number of observations for each mean value was five (n=5 for Long-haired cats and short-haired cats).

[4] Standard error of the mean.

Table 9. Apparent nutrient digestibility using hair-included-feces and hair-removed-feces[1]

Criteria	Treatment[2]		SEM[3]	P-value
	Hair-included	Hair-removed		
Nutrient digestibility, %				
Dry matter	74.12	80.18	0.979	<0.01
Crude protein	75.35	82.34	1.139	<0.01
Crude ash	22.51	37.33	2.547	<0.01
Crude fat	94.51	95.68	0.379	0.13
ADF	57.97	69.63	2.269	0.01
NDF	68.92	78.47	1.767	<0.01
Calcium	1.19	9.77	2.909	0.14
Total phosphorus	14.64	24.49	2.710	0.07

[1] A total of 14 domestic cats with an average age 3.3±1.38year.

[2] Hair-included; hair-included-digestibility, Hair-removed; hair-removed-digestibility

[3] Standard error of the mean.

Table 10. Apparent amino acid digestibility using hair-included-feces and hair-removed-feces[1]

Criteria	Treatment[2]		SEM[3]	P-value
	Hair-included	Hair-removed		
Nutrient digestibility, %				
Total amino acid	77.78	82.03	1.154	0.06
Aspartic acid (ASP)	72.10	77.58	1.401	0.04
Threonine (THR)	73.92	79.05	1.392	0.06
Serine (SER)	74.71	80.98	1.354	0.02
Glutamic acid (GLU)	78.02	81.89	1.117	0.08
Glycine (GLY)	83.86	87.44	0.796	0.02
Alanine (ALA)	79.54	83.42	1.018	0.06
Leucine (LEU)	77.06	81.00	1.277	0.12
Arginine (ARG)	85.70	88.49	0.893	0.12
Cysteine (CYS)	51.14	71.13	3.372	<0.01

[1] A total of 14 domestic cats with an average age 3.3±1.38year.

[2] Hair-included; hair-included-digestibility, Hair-removed; hair-removed-digestibility

[3] Standard error of the mean.

Table 11. Apparent nutrient digestibility using hair-included-feces and hair-removed-feces in long-haired cats[1]

Criteria	Long-haired cats[1]		SEM[3]	P-value
	Hair-included[2]	Hair-removed[2]		
Nutrient digestibility, %				
Dry matter	72.04	80.10	1.830	0.02
Crude protein	73.37	82.35	2.080	0.04
Crude ash	27.67	40.84	4.167	0.12
Crude fat	93.44	95.28	0.676	0.18
ADF	55.63	71.50	4.126	0.07
NDF	65.93	80.77	3.547	0.04
Calcium	3.05	14.60	4.967	0.23
Total phosphorus	14.29	28.20	4.712	0.15

[1] A total of 6 domestic cats with long-hair.

[2] Hair-included; hair-included-digestibility, Hair-removed; hair-removed-digestibility

[3] Standard error of the mean.

Table 12. Apparent amino acid digestibility using hair-included-feces and hair-removed-feces in long-haired cats[1]

Criteria	Long-haired cats[1]		SEM[3]	P-value
	Hair-included[2]	Hair-removed[2]		
Nutrient digestibility, %				
Total amino acid	76.53	85.65	2.283	0.04
Aspartic acid (ASP)	70.65	82.11	2.781	0.03
Threonine (THR)	72.53	83.49	2.749	0.04
Serine (SER)	72.90	84.85	2.748	0.03
Glutamic acid (GLU)	76.87	85.49	2.183	0.04
Glycine (GLY)	82.87	90.04	1.615	0.02
Alanine (ALA)	78.64	86.75	2.003	0.04
Leucine (LEU)	76.11	85.14	2.464	0.06
Arginine (ARG)	85.25	91.44	1.730	0.07
Cysteine (CYS)	42.24	75.40	7.122	0.02

[1] A total of 6 domestic cats with long-hair.

[2] Hair-included; hair-included-digestibility, Hair-removed; hair-removed-digestibility.

[3] Standard error of the mean.

Table 13. Apparent nutrient digestibility using hair-included-feces and hair-removed-feces in short-haired cats[1]

Criteria	Short-haired cats[1]		SEM[3]	P-value
	Hair-included[2]	Hair-removed[2]		
Nutrient digestibility, %				
Dry matter	75.86	80.25	0.954	0.01
Crude protein	77.00	82.33	1.206	0.02
Crude ash	19.56	35.33	3.192	<0.01
Crude fat	95.32	95.98	0.393	0.42
ADF	59.98	68.02	2.455	0.10
NDF	71.49	76.50	1.419	0.08
Ca	0.12	6.44	3.588	0.40
Total P	14.89	21.84	3.320	0.31

[1] A total of 8 domestic cats with short-hair

[2] Hair-included; hair-included-digestibility, Hair-removed; hair-removed-digestibility

[3] Standard error of the mean.

Table 14. Apparent amino acid digestibility using hair-included-feces and hair-removed-feces in short-haired cats[1]

Criteria	Short-haired cats[1]		SEM[3]	P-value
	Hair-included[2]	Hair-removed[2]		
Nutrient digestibility, %				
Total amino acid	78.72	79.32	1.099	0.80
Aspartic acid (ASP)	73.19	74.19	1.311	0.72
Threonine (THR)	74.96	75.71	1.321	0.79
Serine (SER)	76.07	78.07	1.235	0.44
Glutamic acid (GLU)	78.88	79.20	1.085	0.89
Glycine (GLY)	84.61	85.49	0,710	0.55
Alanine (ALA)	80.22	80.93	0.964	0.73
Leucine (LEU)	77.77	77.90	1.254	0.96
Arginine (ARG)	86.04	86.27	0.855	0.90
Cysteine (CYS)	57.82	67.92	2.730	0.06

[1] A total of 8 domestic cats with short-hair

[2] Hair-included; hair-included-digestibility, Hair-removed; hair-removed-digestibility

[3] Standard error of the mean.

Table 15. Comparing apparent nutrient digestibility of long-haired cats and short-haired cats using hair-included-feces[1]

Criteria	Treatment		SEM[2]	P-value
	Long-haired cats	Short-haired cats		
Nutrient digestibility, %				
Dry matter	72.03	75.86	1.263	0.14
Crude protein	73.37	77.00	1.539	0.26
Crude ash	24.86	20.55	3.207	0.53
Crude fat	93.44	95.32	0.623	0.14
ADF	55.63	59.98	3.727	0.58
NDF	65.93	71.49	3.857	0.35
Ca	0.43	2.54	3.846	0.72
Total P	14.29	14.89	4.018	0.95

1 A total of 14 domestic cats with an average age 3.3±1.38year.

2 Standard error of the mean.

Table 16. Comparing apparent amino acid digestibility of long-haired cats and short-haired cats using hair-included-feces[1]

Criteria	Treatment		SEM[2]	P-value
	Long-haired cats	Short-haired cats		
Nutrient digestibility, %				
Total amino acid	76.53	78.72	1.616	0.58
Aspartic acid (ASP)	70.65	73.19	1.914	0.58
Threonine (THR)	72.53	74.96	1.950	0.56
Serine (SER)	72.90	76.07	1.939	0.44
Glutamic acid (GLU)	76.87	78.88	1.539	0.59
Glycine (GLY)	82.87	84.61	1.066	0.44
Alanine (ALA)	78.64	80.22	1.390	0.64
Leucine (LEU)	76.11	77.77	1.815	0.67
Arginine (ARG)	85.25	86.04	1.304	0.78
Cysteine (CYS)	42.24	57.82	5.113	0.20

1 A total of 14 domestic cats with an average age 3.3±1.38year.

2 Standard error of the mean.

Table 17. Comparing apparent nutrient digestibility of long-haired cats and short-haired cats using hair-removed-feces[1]

Criteria	Treatment		SEM[2]	P-value
	Long-haired cats	Short-haired cats		
Nutrient digestibility, %				
Dry matter	80.10	80.25	0.773	0.93
Crude protein	82.35	82.33	0.798	0.99
Crude ash	39.05	35.90	2.563	0.57
Crude fat	95.28	95.98	0.397	0.41
ADF	71.50	68.02	1.377	0.22
NDF	80.77	76.50	1.028	0.03
Calcium	13.08	7.02	4.132	0.49
Total phosphorus	28.20	21.84	3.186	0.35

1 A total of 14 domestic cats with an average age 3.3±1.38year.

2 Standard error of the mean.

Table 18. Comparing apparent amino acid digestibility of long-haired cats and short-haired cats using hair-removed-feces[1]

Criteria	Treatment		SEM	P-value
	Long-haired cats	Short-haired cats		
Nutrient digestibility, %				
Total amino acid	85.65	79.32	1.492	0.03
Aspartic acid (ASP)	82.11	74.19	1.824	0.02
Threonine (THR)	83.49	75.71	1.799	0.03
Serine (SER)	84.85	78.07	1.529	0.02
Glutamic acid (GLU)	85.49	79.20	1.495	0.03
Glycine (GLY)	90.04	85.49	1.000	0.02
Alanine (ALA)	86.75	80.93	1.340	0.02
Leucine (LEU)	85.14	77.90	1.697	0.03
Arginine (ARG)	91.44	86.27	1.147	0.02
Cysteine (CYS)	75.40	67.92	2.397	0.13

1 A total of 14 domestic cats with an average age 3.3±1.38year.

2 Standard error of the mean.


Figure 1. Experimental cage (Cage size : 78 × 54 × 62cm)

Figure 2. Experimental cage (Cage size : 78 × 54 × 62cm)

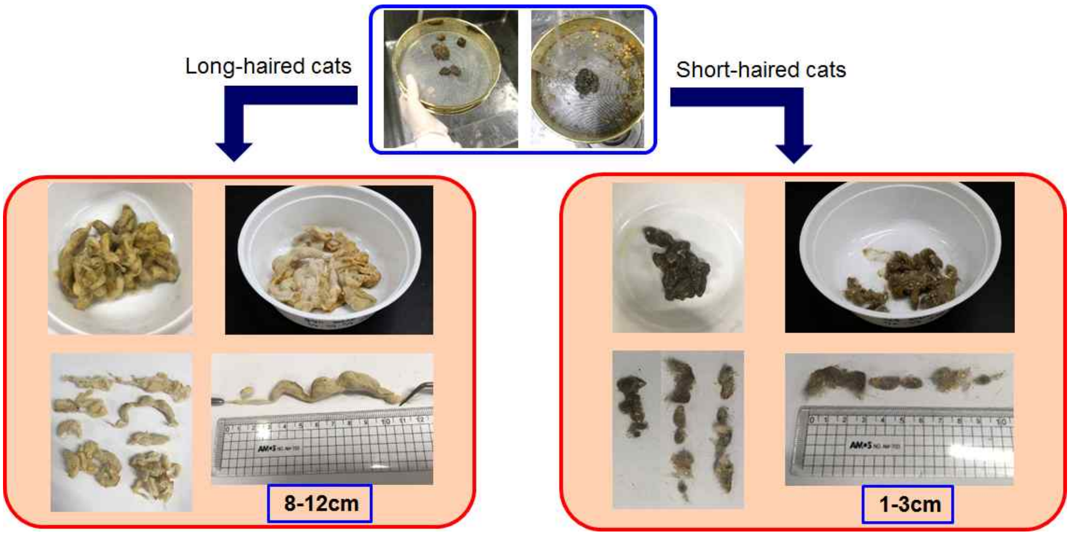

Figure 3. Cats' hairball isolated from feces

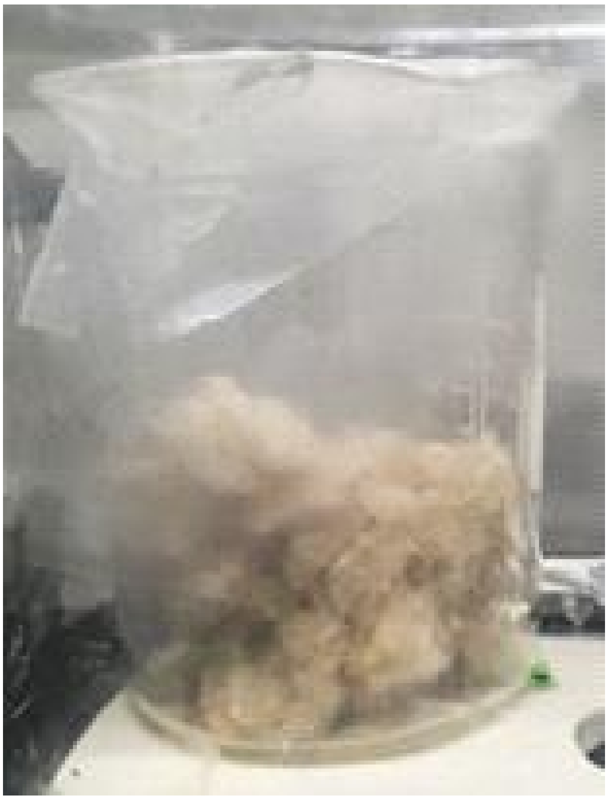

Figure 4. Pooled hairball samples

V. Summary in Korean

본 실험은 고양이 장모종과 단모종의 그루밍 시간과 행동별 시간을 규명하기 위해 수행되었다. 또한 본 실험은 털이 포함된 분 샘플과 털이 제거된 분 샘플을 이용하여 고양이의 그루밍 행동이 고양이의 외관상 소화율 데이터에 미치는 영향을 평가하기 위해 수행되었다.

평균체중 4.3±0.89kg의 평균 연령 3.5±1.38year인 10마리의 성묘를 대상으로 행동관찰을 실시하였다. 고양이 장모종과 단모종의 그루밍 시간과 행동별 시간에서는 유의적인 차이는 나타나지 않았다.

평균체중 4.5±1.21kg의 평균 연령 3.3±1.38year인 14마리의 성묘로 외관상 소화율 실험을 공시하였으며, 처리구는 HI (털이 포함된 분 샘플을 이용하여 계산한 소화율 데이터)와 HR (털이 제거된 분 샘플을 이용하여 계산한 소화율 데이터)로 이루어졌다. 실험 결과, 털이 제거된 분 샘플을 이용하여 계산하는 dry matter, crude protein, crude ash, ADF와 NDF 소화율이 털이 포함된 분 샘플을 이용하여 계산하는 소화율보다 각각 6%, 7%, 15%, 12%, 10% 높은 값을 나타내었다 (P<0.01, P<0.01, P<0.01, P=0.01, P<0.01). 털을 포함하는 분 샘플을 이용하여 계산한 영양소 소화율에서는 장모종과 단모종간의 유의적인 차이가 나타나지 않았으나, 털을 제거한 분 샘플을 이용하여 계산한 NDF 소화율과 아미노산 소화율에서는 장모종이 단모종에 비해 4-8% 높은 값을 기록했다 (P<0.05).

그러므로, 고양이의 외관상 소화율을 계산할 때에는 분 샘플 내의 털의 유무를 고려하여야 한다.

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