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for the Degree of Doctor of Philosophy

Investigation of Various Factors on Nutrients Digestibility of Cat toward Animal Welfare

동물복지를 고려한 고양이 소화율 시험 모델 연구

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Overall Summary

Investigation of Various Factors on Nutrients Digestibility of Cat toward Animal Welfare

The objectives of these experiments were 1) to investigate the effect of adaptation period on nutrient digestibility and blood profiles in cats fed dry feed and canned feed, 2) to evaluate the effect of different levels of deboned chicken meat inclusion as a protein source on nutrient digestibility and blood profiles in cats fed dry feed, and 3) to investigate the effect of environmental housing conditions on stress response and nutrient digestibility in cats.

Experiment I. Effect of Adaptation Period on Nutrient Digestibility and Blood Profiles in Cats fed Dry Feed and Canned Feed

This study was conducted to determine the effect of adaptation period on nutrient digestibility and blood profiles in cats fed dry feed and canned feed. A total of 12 cats (felis catus: four long hair cats and eight short hair cats), averaging body weight (BW) of 4.30 ± 1.05 kg, were used in a 16-day trial. Cats were allocated completely randomized design (CRD) into two treatments according to BW and type of cats' hair (six replicates with two long hair cats and four short hair cats, one cat per cage). Dietary treatments included: 1) canned feed (commercial product) and 2) dry feed (Iskhan, Daehan feed company). When cats fed canned feed, digestibility of dry matter increased at d 4, d 8 and d 12 compared to cats fed the dry feed ($P < 0.05$). The crude protein digestibility of cats fed dry feed was increased compared to canned feed treatment on d 4, d 8, d 12, and d 16, respectively ($P < 0.05$). Cats fed canned feed showed decreased dry matter and crude protein digestibility at d 16 of adaptation period compared to digestibility at d 4 and d 8 of adaptation period ($P < 0.05$). When cats fed dry feed, digestibilities of dry matter, crude protein, crude ash, and ether extract were continually decreased at d 12 and d 16 compared to that of early time at d 4 and d 8 ($P < 0.01$). Consequently content of fecal dry matter of cat was increased when cats were fed dry fed for long period of time ($P=0.01$). In conclusion, the adaptation period needed to reduce when cats fed dry feed (for d 12) compared to cats fed canned feed (for d 16). The albumin level in blood was higher when cats fed dry feed than that of canned feed treatment. No significant difference was observed in total protein, globulin, and creatinine concentrations between two treatments ($P > 0.05$).

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Experiment II. Effect of Different Levels of Deboned Chicken Meat Inclusion as a Protein Source on Nutrient Digestibility and Blood Profiles in Cats fed Dry Feed

This study was conducted to determine the effect of different levels of deboned chicken meat inclusion as a protein source on nutrient digestibility and blood profiles in cats' dry feed. A total of 16 cats (seven long hair cats and nine short hair cats), averaging body weight (BW) of 4.79 ± 1.19 kg, were used in a 21-day trial. Cats were allocated into two treatments according to BW and type of cats' hair (four replicates with two long hair cats and two short hair cats, one cat per cage) in a complete randomized design (CRD). Dietary treatments were: 1) dry feed (basal feed from Daehan feed company), 2) basal feed + 25% deboned chicken meat of protein source, 3) basal feed + 45% deboned chicken meat of protein source, and 4) basal feed + 70% deboned chicken meat of protein source. The digestibility of dry matter and crude protein was increased linearly and quadratically ($P < 0.05$) with increasing deboned chicken meat inclusion in feed. Regression analysis showed that the digestibilities of dry matter and crude protein were the highest at 42.38 and 48.20% of inclusion level of deboned chicken meat, respectively. Moreover, digestibility of ether extract reached the highest point at 45.56% of inclusion level of deboned chicken meat. There were no significant differences in total protein, albumin, globulin, BUN, and creatinine levels in blood among four treatments ($P > 0.05$). In conclusion, these results demonstrated that inclusion of deboned chicken meat as a protein source improved the cats' nutrient digestibility, and it was the highest approximately 45% of deboned chicken meat inclusion.

Experiment III. Effect of Environmental Housing Conditions on Nutrient Digestibility and Stress Response in Cats

This study was conducted to determine the effect of environmental housing conditions on nutrient digestibility and stress response in cats. A total of 12 cats (six long hair cats and six short hair cats), averaging body weight (BW) of 4.30 ± 0.85 kg, were used in a 21-day trial. Cats were allocated into two different breeding environments according to BW and type of cats' hair in six replicates with three long hair cats and three short hair cats, one cat per cage by complete randomized design (CRD). Treatments were: 1) cats in the small cage were housed singly in stainless-steel cages measuring $0.77 \times 0.51 \times 0.63$ m (length × width × height) 2) cats in the large room were housed singly in wooden wall room measuring $1.2 \times 1.5 \times 2.5$ m, respectively. When cats were housed in the large room for 13~16d had a greater the digestibility of crude protein than that of small cage treatment ($P < 0.05$). A slight increased digestibility of dry matter ($P = 0.09$) was observed when cats were housed in the large room. However, no significant differences ($P > 0.05$) were observed in digestibility of dry matter,

crude protein, crude ash, and ether extract between two treatments during d 17 ~ 20. There was no significant difference in cortisol level in blood between two treatments at initial, d 7, and d 21 of experiment. The stress response was decreased significantly in cats housed in large room during d 8 ~ 21. However, any significant difference in stress levels was not observed in cats housed in small cage in different experimental periods. In conclusion, cats housed in the large room improved the digestibility of dry matter and crude protein during d 13 ~ 16 and decreased the stress levels compared to cats housed in the small cage treatment.

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List of Abbreviations

AOAC	:	Association of official analytical chemists
BW	:	Body weight
BUN	:	Blood urea nitrogen
CP	:	Crude protein
Ca	:	Calcium
CRD	:	Completely randomized design
DM	:	Dry matter
Fig	:	Figure
MCP	:	Monocalcium Phosphate
NRC	:	National Research Council
SAS	:	Statistical analysis system
SEM	:	Standard error of means
ME	:	Metabolizable energy

Chapter I.   General Introduction

Animal welfare is attracting increasing interest worldwide and it means the well-being of animals. The standards of "good" animal welfare vary considerably between different contexts. These standards are under constant review and are debated, created and revised by animal welfare groups, legislators and academic fields in the world (Grandi and Hauser, 2002; Hewson, 2003). Animal welfare science uses various measures, such as longevity, disease, immunosuppression, behavior, physiology, and reproduction (Broom, 1991).   Concern for animal welfare is often based on the belief that non-human animals are sentient and that consideration should be given to their well-being or suffering, especially when they are under the care of humans. These concerns can include how they are used in scientific research, how they are kept (as pets, in zoos, farms, circuses, etc.), and how human activities affect the welfare and survival of wild species. Terrestrial Animal Health Code of World Organization for Animal Health defines animal welfare as "how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behavior, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling. Behavioral enrichment is an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psychological and physiological well-being (Shepherdson, 1998). The goal of environmental enrichment is to improve or maintain an animal's physical and psychological health by increasing the range or number of species-specific behaviors, increasing positive utilization of the captive environment, preventing or reducing the frequency of abnormal behaviors such as stereotypies, and increasing the individual's ability to cope with the challenges of captivity. The purpose of behavioral enrichment is to improve the overall welfare of animals in captivity and create a habitat similar to what they would experience in their wild environment.

The popularity of the cat as a pet has increased over the last decades (Marchand and Moore, 1991). However, currently, the studies on cat's welfare is limited, the minimum spatial requirement for singly housed cats remains unknown. The factors which influence the adaptation of cats shelter to be not well-known. Therefore, the objective of this study was to evaluate the effect of different types of feed, different levels of deboned chicken meat inclusion as a protein source, and environmental housing conditions on adaptation period, stress response, and nutrient digestibility in cat housed in a large room or small cage.

Chapter II. Review of Literature

1. Feed type in cats

1.1. Introduction

Recently, pet feed recall seems to have resurrected concerns about the suitability of feeding dry feed to cats (Buffington, 2008). Recalls can be frightening for pet owners and veterinarians alike. One may need to act in the face of significant uncertainty about the extent of the threat, and the stakes, pets' lives are high. Many pet owners have a strong emotional bond with their pet and naturally want to do their best for their pet's health and welfare because feed plays an important role in pets' well-being. The purpose of this paper is to review some of the issues surrounding dry feed and canned feed for cats. For a feed to be satisfactory, it must contain all of the necessary nutrients in the proper proportions (complete and balanced), be sufficiently palatable and digestible for the pets consuming it to meet their nutritional needs in the volume consumed, and it must be safe. The pet feed recall was the result of an inadvertent inclusion of a toxin that made the feeds unsafe; there was no evidence that the feeds were nutritionally unsatisfactory in any other way. Despite the fact that the recall was for toxicological rather than nutritional reasons, it provided the opportunity for some to question the nutritional adequacy of pet feeds (Buffington, 2008).

1.2 Cat characters

The domestic cat (Latin: Felis catus) is a small, typically furry, carnivorous mammal. Cats are often valued by humans for companionship and for their ability to hunt vermin. Cats are similar in anatomy to the other felids, with a strong flexible body, quick reflexes, sharp retractable claws, and teeth adapted to killing small prey. Cat senses fit a crepuscular and predatory ecological niche. Cats can hear sounds too faint or too high in frequency for human ears, such as those made by mice and other small animals. They can see in near darkness. According to Buffington, (2008), who indicated that cats are less efficient than some other mammals are at metabolizing dietary carbohydrates under certain circumstances. This observation appears to have led to speculation that long term feeding of carbohydrates may have detrimental effects on the health of cats. Concerns have been raised that some association between the carbohydrate content of dry cat feeds and risk of obesity and type 2 diabetes mellitus may exist, although the relationship, if any, is far from clear.

1.3 Dry feed type

Pet feed comes in many different shapes, sizes and textures these days such as dry feed or

canned feed. Dry feed looks like a biscuit or kibble and comes in bags with various sizes. It does contain water, usually up to about 11%, which is added into the mix of ingredients to make dough, rather like bread-making. The dough will rise in the cooker and then is pushed through a small hole or die, with pressure. This process causes the dough to heat up, and it is cooked as it is pushed through. A cutter then cuts the cooked dough coming through into kibbles. The die can have holes of different shapes and sizes which is what gives the kibble its appearance. Some kibbles are simply round in shape while others might be fish shaped, heart or cubed depending on the manufacturer's preferences. Dry feed is less expensive, more convenient to feed as you can buy a larger quantity in one go and takes less room to store than feeding wet feed for the same number of days. Dry feed can have some benefit in helping to keep teeth cleaner as the kibbles can have an abrasive action. Some, such as Hill's Science Plan Oral Care, is specially designed to work even harder by wiping the teeth clean when the animal bites into the kibble.

1.4 Canned feed type

Canned feeds contain between 70 and 85% water, mixed in with the 'dry' ingredients. This means that the product, whether in a can, a pouch or tray, will weigh much more than the equivalent dry feed. Transporting and shipping wet products is therefore much more costly than dry and this is part of the reason why feeding tins is a more expensive way to feed your pet. There are some other differences between the ingredients used in a wet and a dry feed. Wet feed often contains higher amounts of protein and fat than dry feed and this is why it is often perceived as tastier by the pet. Ingredients such as meat, meat meal or animals derivatives will appear higher on the label in canned feed. Often there is very little or no cereal in a wet feed, although there can still be carbohydrate provided in any vegetable ingredient. Though high in water, you won't find it swishing around in the can. This is because the water is trapped by other ingredients such as gelatin or some sugars which hold it in place and form a jelly which helps to evenly distribute the feed chunks or suspend them. Wet feeds don't tend to have preservatives as they are intended to be used up too soon to allow them to become rancid. An opened can should be stored in the fridge and used up within a few days. Cats are not great at drinking water. For cats prone to urinary problems, feeding a wet feed can help them to take in more water and so help them to urinate more often. However, A previous study shown that there was also no significant difference in body condition of cats fed mainly dry or mainly canned feed, and there was no significant effect of feeding of either canned or dry feeds on demand (Russell et al., 2000).

1.5 Domestic market of pet feed

Most of the pet feed bought by the Korean consumer is dry feed, although canned wet feed is considered a premium product and is available. Korean dry pet feed makes up 95 percent of the market while wet canned pet feed makes up 5 percent. Therefore, we conducted this study to determine the effect of adaptation period on nutrient digestibility and blood profiles in cats fed dietary dry feed and canned feed.

2. Protein source nutrition

2.1 Nutrient requirement of cats

Cats are one of the few species that are strictly carnivorous, which explains their unusual requirement for specific nutrients, such as arachidonic acid, vitamins A and D and many B vitamins (particularly niacin), taurine, and arginine, which cannot be endogenously synthesized in sufficient amounts to meet their needs (MacDonald et al., 1984; Morris, 2002). However, it is their unique need for large amounts of dietary protein (specifically, dispensable nitrogen) that separates them from noncarnivorous species (MacDonald et al., 1984; Morris, 2002). Many of the dietary requirements for specific amino acids, fatty acids, and vitamins that have been observed in cats are suggested to be a result of their evolutionary adaptation for feed availability from animal sources (Morris, 2002). Several reviews of feline nutrition provide details of the specific needs that dictate their feed composition (Morris, 2002; Zoran, 2002). Although healthy animals of many species can accommodate large amounts of dietary protein, cats are particularly adapted both physiologically and metabolically for high protein intake (feeds containing up to 70% protein are acceptable for cats) as a result of the high (NRC, 2006), and fixed rate of activity of the enzymes of protein degradation and disposal (including aminotransferases and urea cycle enzymes) in cats (Rogers et al., 1976; Rogers and Morris, 2002). This unique aspect of feline enzyme function was clearly evident in which investigators found that the activity of some hepatic aminotransferases and urea cycle enzymes did not differ when cats were fed feeds high (54% ME) or low (14% ME) in protein (Rogers et al., 1976).

2.2 Protein requirement

Lack of metabolic flexibility becomes critically important when cats are in appetent (as a result of disease or other health conditions, including gastrointestinal tract disturbances or hepatic lipidosis), are consuming feeds containing poor-quality protein, or are not consuming a sufficient amount of protein in the feed to meet their needs. Protein is the primary macronutrient responsible for maintenance of muscle mass (more specifically, indispensable amino acids and nitrogen) (Fujita et al.,

2007; Vasconcellos et al., 2009). The preservation of muscle mass is a function of 2 processes: consumption of a sufficient amount of high-quality protein (with adequate indispensable amino acid content) and adequate neuromuscular activity to promote maintenance of the tissue mass (Evans, 1997; Kimball et al., 2002). Furthermore, lean body mass is a primary determinant of a cat's resting energy requirement (Vasconcellos et al., 2009); thus, dietary protein intake (on an energy basis) and the amount of activity are 2 key variables that must be considered because the loss of lean muscle tissue is a potentially important contributor to energy imbalances in neutered, sedentary indoor cats (Zoran and Buffington, 2011).

Dietary protein requirements for cats traditionally have been based on minimum requirements for short-term nitrogen balance (the state at which nitrogen intake equals nitrogen excretion) in the presence of adequate energy intake. For the nitrogen-balance method, subjects are fed varying amounts of protein and the requirement is deemed to be at the level of intake that maintains neutral or slightly positive nitrogen balance (Morris, 2002). This state can be difficult to define for cats because there is not always a definitive plateau (Morris and Idiosyncratic, 2002; Rogers and Morris, 2002). Green et al. (2008) and Heinze et al. (2009) reported that 2.5 to 2.7 g of protein/kg of BW were sufficient to maintain nitrogen balance for the short duration of those studies (approximate 3 weeks). In the longer term, NRC (2006) indicated that for evaluation of commercial dry, expanded feeds that have provided sustained maintenance for months to years, none were found with < 265 g of crude protein/kg of feed that contained 4.0 kcal ME/g. For example, an active 4.0kg (8.8-lb) cat consume 65 kcal/kg of BW/d (29.5 kcal/kg of BW/d), which was derived from the NRC recommended intake of $100 \times (BW\ kg^{0.67})$, translates to 4.3 g of protein/kg of BW/d (1.95 g of protein/kg of BW/d) (NRC, 2006). However, for an inactive, neutered 4.0 kg cat consuming fewer calories (e.g., 45 kcal/kg of BW/d, feeding the same feed would translate into a protein intake of 3.0 g of protein/kg of BW/d.

2.3 Raw meat as protein source for cats

The feeding of raw meat-based feed to cats has received increasing attention in recent years. Raw meat feeds are primarily formulated using the nutrient requirements of domestic cats. Observations of wild felids also are utilized for feed formulation, including feeding habits, fecal analysis, and composition of prey. However, composition of prey species is rarely determined, and observations of feeding habits and fecal analysis can be of limited use without determination of prey composition. Digestibility trials in captive exotic species, when possible, are also important benchmarks. Raw meat feeds for captive exotic felids are most often formulated to use meat trimmings. These sources contain excess connective and other tissues after slaughter that is highly variable and can be high in fat. The resulting feeds also are highly variable in nutrient composition. For example, reported dietary dry matter (DM), CP, and fat content for such feeds fed to exotic species ranged from 29 to 40%, 38 to

84%, and 8 to 38%, respectively (Edwards et al., 2001; Bechert et al., 2002). Digestibility of raw meat-based feeds appears to depend on species and total dietary fiber content (Kerr, 2012); however, few interactions have been reported between feed and species for feed digestibility (Vester et al., 2010a). Not surprisingly, reported values for apparent total tract digestibility are also highly variable [DM: 66 to 89%, CP: 73to 96%, fat: 73 to 99% (Edwards et al., 2001; Vester et al., 2008, 2010a,b)].

Given their high protein concentration, meat tissues in raw meat and whole prey sources help meet the high protein requirement of domestic cats [adult cats: 160 g CP/kg DM for feeds containing 4,000 kcal metabolizable energy (ME)/kg; (NRC, 2006)]. Low-quality or incomplete proteins also can lead to imbalances (Kerr, 2012). Natural cat feed should carry a minimal protein content of 50 - 70% (Peterson, 2011). Others estimated cat protein requirement to be between 50% and 60% (Myrcha and Pinowski, 1970; Vonduruska, 1987; Crissey et al., 1999; Zoran, 2002). Previous literature had indicated that raw meat–based feeds had significant higher digestibility of crude protein, energy or dry matter than the extruded feeds (Crissey et al., 1997; Vester et al., 2010b). Likewise, Kerr et al. (2012) reported that apparent total tract of DM, CP, fat, and GE digestibility were greater when cats consumed raw beef based feed compared with cats fed extruded feed. Herein, we focus on the use of different protein levels from raw meat in the feed of cats in term of their beneficial impact on nutrient digestibility and stress response of cat.

3. Environmental housing conditions

3.1 Introduction

The way a cat is housed will have a significant impact on its welfare. The main housing conditions include research facilities; boarding, breeding or quarantine catteries; shelters and sanctuaries, but their findings can be applied to other situations. General recommendations are made, with regard to the quality of space cats need, the quality of the space (that is, what its internal features should provide) and the need of cats to have contact with others cats and with human. In addition, the requirements to live in a stimulating sensory environment, to have opportunities to explore and play, and to have appropriate access to feed and water, are described (Ottway and Hawkins, 2003). Particular considerations for cats kept in research facilities, in shelter environments are mentioned. For pet cats in the large room or small cage with the different facilities are discussed.

3.2 Shelter for cat

Pervious research has been carried out on the behavior and welfare of cats kept in different environments. Cats housed communally in small group (between four and seven cats) in rooms in a shelter. Newly introduced cats were aggressive towards others, and showed behaviors indicative of

high levels of stress (such as vocalizing and attempting to escape) (Durman, 1991), the stress is also likely to be due to confinement in a single cage (Cauvin et al., 2003). In particular, the stress of confinement might be associated with an increased risk of disease conditions. Common definitions of environmental enrichment comprise the description of the addition of one or more 'factors' to a relatively impoverished environment to examine the impact of these variables on the physical and psychological welfare of the animal involved (Chamove, 1989; Newberry, 1995; Shepherdson, 1998 ; Young, 2003). These 'factors' commonly refer to any physical, social, design, or management features that may improve the behavioural microhabitat of captive animals (Shepherdson, 1998; Young, 2003 ; Smith and Corrow, 2005).

Cat are more likely to respond to poor environmental conditions by becoming inactive and by inhibiting normal behaviors such as self-maintenance (feeding, grooming and elimination), exploration or play, than by actively showing abnormal behavior (McCune 1992, Rochlitz 1997). Cats with illness may also modify their behavior in a similar way. Keeping cats in an enriched, stimulating environment that encourages a wide range of normal behaviors will not only enhance their welfare, but also make it easier for owners and caretakers to detect illness. For example, according to Rochlitz (1999), the enclosure should be large enough to allow cats to express a range of normal behaviors, and to permit the caretaker or owner to carry out cleaning procedures easily. When cats are housed in groups, there should also be enough space for cats to keep themselves separate from others. Enclosures should contain structures that make maximal use of the vertical dimension, such as shelves, climbing frames, platforms, hammocks and raised walkways placed at various heights. Resting areas where cats can retreat to and be concealed, in addition to 'open' resting areas (e.g. shelves), are essential for their well-being. Visual barriers, such as vertical panels, can also be used to enable cats to get away from others and hide. If it is necessary to observe the cat closely, a box open on two or three sides, or a deep-sided tray, can be used. Most cats play alone rather than in groups (Podberscek et al 1991), so the cage should be large enough to permit them to play without disturbing other cats.

3.3 Adaptation in a new environment

In an animal shelter, the adjustment process to either the single or the group-housing condition takes 2-5 weeks, but shows great individual variation among cats (Smith et al., 1994; Rochlitz et al., 1995; Kessler and Turner, 1997). However, factors influencing the adaptation of cats to animal shelters have received little attention. Roy (1992) studied spatial factors influencing the welfare of cats in shelters, and recommended the provision of hides as well as elevated shelves made of wood. Leyhausen (1979) found that density affects the social behavior of cats in group enclosures. In recent years, research has been carried out on the behavior and welfare of cats kept in different environments. These include laboratories (Podberscek et al., 1991; McCune, 1992; van den Bos and

de Cock Buning, 1994, van den Bos, 1998), animal shelters (Durman, 1991; McCune, 1992; Roy, 1992; Smith et al., 1994; Kessler and Turner, 1997; Rochlitz, 1997), quarantine and boarding catteries (Kessler and Turner, 1997) and the home (Bernstein and Strack, 1996).

Within an enclosure (the internal environment), there should be adequate separation between feeding, resting and elimination (litter tray) areas. The enclosure should be large enough to allow cats to express a range of normal behaviors, and to permit the caretaker or owner to carry out cleaning procedures easily. When cats are housed in groups, there should also be enough space for cats to keep themselves separate from others. Conflict-regulating mechanisms are important to maintain stability of groups in some species (van den Bos, 1998), but group-living cats lack distinct dominance hierarchies and post-conflict mechanisms such as reconciliation (Bos and Buning, 1994; van den Bos, 1998). They are not adapted to living in close proximity to each other and reduce the likelihood of aggression by establishing distances between themselves (Leyhausen, 1979). If an enclosure is too small, there may be an increase in agonistic encounters or cats will attempt to avoid each other by decreasing their activity (Leyhausen, 1979; Bos and Buning, 1994). The vertical dimension is particularly important as regards the provision of appropriate internal complexity, so cages should be of adequate height (Rochlitz, 1999). However, there are no clear guidelines on the minimum space required and optimum group density in boarding catteries and animal shelters.

4. Conclusion

Pet feed comes in many different shapes, sizes and textures such as dry feed or canned feed. Thus, many pet owners have a strong emotional bond with their pet and naturally want to do their best for their pet's health and welfare. When a cat is confined in a novel environment, such as an animal shelter, it can be stressful. Since feed plays an important role in pets' well-being, pet owner concerns about pet feeds readily understandable. For a feed to be satisfactory, it must contain all of the necessary nutrients in the proper proportions (complete and balanced), be sufficiently palatable and digestible for the pets consuming it to meet their nutritional needs in the volume consumed, and it must be safe. However, there are no clear guidelines on the minimum space required, optimum group density in boarding catteries and animal shelters as well as a satisfactory feed for cats. Therefore, further scientific investigation is needed to know the effect of different type of feed, different levels of protein supplementation, and housing environmental conditions on adaptation time, stress response, and nutrient digestibility in cats.

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Chapter III. Effect of Adaptation Period on Nutrient Digestibility and Blood Profiles in Cats fed Dry Feed and Canned Feed

ABSTRACT: A total of 12 cats (four long hair cats and eight short hair cats) with an average body weight (BW) of 4.30 ± 1.05 kg were used in a 16-day trial to determine the effect of adaptation period on nutrient digestibility and blood in cats fed dietary dry feed and canned feed. Cats were allocated completely randomized design (CRD) into two treatments according to BW and type of cats' hair (six replicates with two long hair cats and four short hair cat, one cat per cage). Dietary treatments included: 1) canned feed (commercial product), 2) dry feed (Daehan feed company). The crude dry matter digestibility significantly increased in cats fed canned feed compared to cats fed dry feed on d 4, d 8 and d 12 adaptation periods. Cats fed the dry feed significantly increased crude protein digestibility on d 4, d 8, d 12, and d 16 adaptation periods compared to cats fed the canned feed. Cats fed canned feed had lower dry matter and crude protein digestibility on d 16 of adaptation period than those of cats on d 4 and d 8 of adaptation period (P < 0.05). The dry matter, crude protein, crude ash, and ether extract digestibility of cats fed the dry feed significantly decreased (P < 0.01) on d 12 and d 16 compared to those of cats on d 4 and d 8. Fecal dry matter of cat significantly increased (P=0.01) on d 12 and d 16 compared to those of cats on d 4 and d8. In conclusion, the adaptation period shortened 4 days in cats fed dry feed (on d 12) compared to cats fed canned feed (on d 16). Cats fed dry feed had a higher on the albumin levels in blood were higher in cats fed dry feed than that of cats fed canned feed. There were no significant difference (P > 0.05) observed in total protein, globulin, and creatinine concentrations between two treatments.

Key words: Adaptation period, canned feed, cats, dry feed, nutrient digestibility

1. INTRODUCTION

In the wild, cats can consume a varied feed, mainly composed of birds, rodents, and small prey (Woods et al., 2003). However, in captivity, feed is normally elaborated empirically, according to the choices and habits observed in wild animals, by trial and error and taking into account the body condition of each animal. Nevertheless, such factors may not be sufficient to attend the individual nutritional demands (Saad et al., 2007; Clauss et al., 2010). Nowadays, the use of commercial feed for pets is becoming more popular and getting more concern of pet owner and scientist. For instance, Gaskell (1985, 1989) reported that cats fed solely dry feed have a lower water intake and lower urine volume than cats on a wet feed even if they have constant access to fresh water.

Besides, cats have been shown to have 14 days of period of adjustment, unlike 7 days, and most cat digestibility studies are now 21 days, including 14 days of adaptation (Nott et al., 1994). Other studies showed that in an animal shelter, the adjustment process to either the single- or the group-housing condition takes 2-5 weeks (Smith et al., 1990; Rochlitz et al., 1995; Kessler and Turner, 1997). However, factors influencing the adaptation of cats to animal shelters have received little attention. Roy (1992) studied spatial factors influencing the welfare of cats in shelters, and recommended the provision of hides as well as shelfs made of wood. In light of recent research trends emphasizing animal welfare and experimental ethics, it is not desirable to conduct long-term metabolism experiments in a narrow cage, and validation studies are needed. Therefore, this study was conducted to determine the effect of dietary dry feed and canned feed supplementation on nutrient digestibility and four different adaptation periods in cat shelter.

2. MATERIALS AND METHODS

The experimental protocol used in this study was approved by the (SNUIACUC-160712-22) and complied with the guidelines provided by the Animal Care and Use Committee of Seoul National University. This experiment was carried out at Irion Animal Hospital (445 Dosan-Dong, Gangnam-gu, Seoul, Korea). The cats' health management and basic general experiment management (feeding, taking fecal samples and caring) was carried out by Irion animal hospital veterinarian and their guideline.

2.1 Experimental design, animals and feeds

A total of 12 adult domestic cats (Felis catus, four long hair cats and eight short hair cats) with an average body weight (BW) of 4.30 ± 1.05 kg were used in a 16-day trial. Cats were allocated

completely randomized design (CRD) into two treatments according to BW and type of cats' hair (six replicates with two long hair cats and four short hair cats, one cat per cage). Dietary treatments included: 1) canned feed (commercial product), 2) dry feed (Daehan feed). All feeds were formulated to meet or exceed NRC (2006) nutrient requirements (Table 1). The daily amount of feed was calculated considering the calories of dry feed and canned feed.

Cats were individually housed in stainless-steel cages (0.77×0.51×0.63 m) at the Irion animal hospital (445, Dosan-daero, Gangnam-gu, Seoul, Republic of Korea). Each cage was equipped with a feed dish, water dish that allowed throughout the experiment, fecal box (0.33×0.44×0.16m) and a shelf (0.51×0.29m). The shelter was installed at 0.3m high from the floor (Figure 1). Lighting was automatically regulated to provide 14 h of fluorescent light with starting at 6 am and 10 h of darkness, supplemented with light infrared by recording web cam. During the adaptation period, cat litter was used to put in feces box, and after the experiment was started the cat litter was replaced by pads. The target room temperature and humidity were 23 ± 2°C and 50 ± 10%, respectively.

Each day, feed was weighted and divided into 2 equal proportions, placed in stainless steel bowls, and left out at 09:00 and 16:00 h. Bowls were removed before the next meal, and any remaining feed was weighted and recorded. Water was provided ad libitum. Fecal boxes were cleaned between 08:00 and 09:00 h, and between 15:00 and 16:00 h, and the amount of feed was fed to the amount corresponding to the maintenance energy ($100 \times$ body weight$^{0.67}$) of cats (NRC, 2006). The fresh water was supplied from time to time.

Figure 1. Metabolism cage (0.77×0.51×0.63 m)

2.2 Sampling and measurements

During the experimental period, all fresh fecal grab samples were daily collected in each pen

to calculate the apparent total tract digestibility for dry matter, crude protein, crude ash, and ether extract according to the adaptation period of cats (d 0 - 4, d 5 – 8, d 9 – 12, and d 13-16). All feces samples were immediately stored in a zipper bag at −20°C until analysis. At the analysis time, the fecal samples were dried at 60°C for 72 h in a drying oven (AMP Daw Model 18, Daihan scientific, Korea) and finely ground to pass through a 1-mm screen (Wiley Mill intermediate, Thomas Scientific).

Total moisture was determined by air-drying the collection at 60°C, followed by an equilibration and moisture determination at 105°C (Harris, 1970). The fecal dry matter was then calculated using the following formula:

Fecal dry matter (%) = 100 – moisture

Before blood collection, cats were feed-deprived overnight and anesthetized with Sevo-flurane gas using a facial mask. Blood samples were collected via jugular venipuncture, transferred to non-heparinized tubes to obtain serum. All samples were centrifuged within 1 h of collection. Serum and plasma tubes were centrifuged (1,100-1,300 × g for 15 min) at 4°C. The creatinine concentrations were determined using an Astra-8 Analyzer (Beckman Instruments, Inc., Brea, CA 92621). The blood urea nitrogen (BUN) and concentrations of albumin, globulin in the serum samples were measured using an automatic blood analyzer (ADVIA 120, Bayer, USA). Serum total protein was determined using an automatic biochemistry analyser (HITACHI 747, Hitachi, Tokyo, Japan).

2.3 Laboratory analysis

Feed samples were dried at 60°C for 72 h, and were finely ground to pass through a 1-mm screen. Samples were analyzed for the moisture content (method 930.15; AOAC 1995), the crude ash content (method 942.05; AOAC 1995), the crude fat content (method 920.39; AOAC 1995), the crude protein content (method 988.05; AOAC 1995), the calcium (method 984.01; AOAC 1995), and phosphorus (method 965.17; AOAC 1995).

2.4 Statistical analysis

All data were analyzed by the student's t-test (SAS Institute, 2009) to evaluate significant difference of values between canned feed and dry feed. Significance of the experimental data was verified by Fisher's test. Statistical analysis showed that there was statistically significant difference when the p-value was less than 0.05 and statistically highly significant difference when the value was less than 0.01.

3. RESULTS

In the current study, cats fed the canned feed significantly increased (P < 0.05) the dry matter digestibility on d 4, d 8, and d 12 compared to cats fed the dry feed (Table 2). The crude protein digestibility of cats fed the dry feed increased (P < 0.05) compared to cats fed the canned feed on d 4, d 8, d 12, and d 16. However, no significant difference (P > 0.05) was observed in the crude ash and ether extract between two treatments on d 4, d 8, d12, and d 16.

When cats fed the canned feed, there was no significant difference observed in crude ash and ether extract among d 4, d 8, and d 12 of adaptation period (Table 3). However, a significant decrease (P < 0.05) was observed on dry matter and crude protein digestibility on d 16 of adaptation period compared to those of cats on d 4 and d 8 of adaptation period.

When cats fed the dry feed, there was no significant difference observed in dry matter, crude protein, crude ash, and ether extract digestibility between d 4 and d 8 and between d 12 and d 16 of adaptation period (P > 0.05). However, the dry matter, crude protein, crude ash, and ether extract digestibility of cats fed the dry feed significantly decreased (P < 0.01) on d 12 and d 16 compared to those of cats on d 4 and d 8 (Table 4).

The fecal dry matter was significant higher (P < 0.05) on d 12 of adaptation period than the fecal dry matter on d 4 and d 8 of adaptation period in cats fed dry feed (Table 5). However, there was no significant difference observed in cats fed canned feed among d 4, d 8, d 12, and d 16 of adaptation period (P > 0.05).

Cats fed the dry feed had higher (P < 0.05) albumin concentrations in blood than that of cats fed the canned feed (Table 6). However, no significant difference (P > 0.05) was observed in total protein, globulin, BUN, and creatinine concentrations between two treatments.

4. DISCUSSION

Nott et al. (1994) reported that there was no significant different observed in dry matter, energy and fat between during d 8-14 and d 15-21 of adaptation period when cats fed dry feed. However, there was a significant difference observed in protein between during d 8-14 and d 15-21 of adaptation period. Similarly, in our study cats fed canned fed had a significant lower in dry matter and crude protein digestibility on d 16 of adaptation period compared to those of cat on d 4 and d 8. Besides, the dry matter, crude protein, crude ash, and ether extract digestibility of cats fed the dry feed significantly decreased (P < 0.01) on d 12 and d 16 of adaptation period compared to those of cats on d 4 and d 8 of adaptation period with no significant difference being observed in dry matter, crude protein, crude ash, and ether extract digestibility in cats fed dry feed between d 12 and d 16 of adaptation periods. According to Kendall et al. (1982) who reported that when cats were fed a feed

designed that meets their nutritional requirements, which resulted in no significant difference in apparent digestibility of cats. As a result, after a significant decrease of nutrient digestibility in cats fed dry feed on d 12 of adaptation period, the nutrient digestibility was not affected on d 16 of adaptation period compared to the nutrient digestibility on d 12 in cats fed dry feed. In addition, the feces DM significantly increased on d 12 compared to the feces DM on d 4 and d 8, and then the water content stable after d 12. The possible reason for this result could be due to an adaptation of the cats to the feeds after a longer period of feeding. The microflora of the gut may change or there may be changes in enzyme secretion due to increases in the number of secreting cells on the villi of the lumen. Both factors could affect absorption of water in both the small intestine and cecum (Nott et al., 1994). Therefore, we hypothesis that it is possible to evaluate the reliability of the nutrient digestibility value according to the adaptation period by comparing the nutrient digestibility after the last adaptation period (d 16) of this experiment for canned feed, and the nutrient digestibility will be estimated by collecting the adaptation period on d 12 for dry feed in cats.

Albumin is a type of protein the liver produces. It's one of the most abundant proteins in your blood. A proper balance of albumin is to keep fluid from leaking out of blood vessels. Albumin also carries vital nutrients and hormones, and provides your body with the proteins it needs to maintain growth and repair tissue. Low albumin levels can reflect liver or kidneys disease and also can be seen in inflammation, shock and malnutrition. In this study, cats fed dry feed had higher albumin levels in blood. Increased serum albumin concentrations have been associated with intake of high-protein feeds (Mutlu et al., 2006). Therefore, the increase of crude protein in cat fed dry feed compared to cats fed canned could be a possible reason for increased serum albumin concentrations. We hypothesis that a higher albumin in this study could lead to improving cats' health in cats fed dry feed compared to cats fed canned feed.

5. CONCLUSION

In conclusion, our study suggested that the cats' digestibility after 16 days of adaptation period might be reliable when cats were fed canned feed. However, when cat fed dry feed, the cats' digestibility is highly reliable after 12 days of adaptation period because no significant difference was observed in nutrient digestibility after 12 days of adaptation period. In addition, the albumin levels were higher in cats fed dry feed than that of cats fed canned feed.

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Table 1. Analyzed composition of the experimental feeds (%)

Items	Canned feed	Dry feed
Moisture	75.15	6.47
Crude protein	14.59	33.01
Crude ash	2.61	7.65
Crude fat	28.06	15.40
Calcium	0.42	1.33
Total phosphorus	0.43	0.89
Total fiber	0.20	3.59

Table 2. Effect of adaptation period on nutrient digestibility in cats fed dry feed and canned feed

Items	Treatment		SEM[1]	P-value
	Canned feed	Dry feed		
d 4				
Dry matter, %	85.31	79.03	1.484	0.02
Crude protein, %	68.60	79.95	2.460	0.03
Crude ash, %	30.27	26.86	6.989	0.84
Ether extract, %	95.40	95.93	0.436	0.61
d 8				
Dry matter, %	84.64	80.46	1.0759	0.04
Crude protein, %	67.78	81.05	2.771	0.03
Crude ash, %	25.51	31.30	3.994	0.49
Ether extract, %	95.68	95.41	0.379	0.76
d 12				
Dry matter, %	81.29	73.18	1.515	<0.01
Crude protein, %	59.54	74.12	2.875	0.02
Crude ash, %	8.85	8.56	2.794	0.96
Ether extract, %	94.74	92.62	0.704	0.14
d 16				
Dry matter, %	78.02	75.58	0.863	0.16
Crude protein, %	51.46	76.75	4.164	<0.01
Crude ash, %	12.90	14.23	4.185	0.88
Ether extract, %	94.09	93.23	0.527	0.45

[1]Standard error of means

Table 3. Effect of adaptation period on nutrient digestibility in cats fed canned feed

Items	Adaptation period				SEM[1]	P-value
	d4	d8	d12	d16		
Dry matter, %	85.31[a]	84.64[a]	81.29[ab]	78.02[b]	1.042	0.03
Crude protein, %	68.60[a]	67.78[a]	59.54[ab]	51.46[b]	2.315	0.01
Crude ash, %	30.27	25.51	8.85	12.90	5.121	0.42
Ether extract, %	95.40	95.68	94.74	94.09	0.487	0.69

[1]Standard error of means
[ab] Means in the same row with different superscripts differ ($P < 0.05$)

Table 4. Effect of adaptation period on nutrient digestibility in cats fed dry feed

Items	Adaptation period				SEM[1]	P-value
	d4	d8	d12	d16		
Dry matter, %	79.03[a]	80.46[a]	73.18[b]	75.58[b]	0.743	<0.01
Crude protein, %	79.95[a]	81.05[a]	74.12[b]	76.75[b]	0.714	<0.01
Crude ash, %	26.86[a]	31.30[a]	8.56[b]	14.23[b]	2.481	<0.01
Ether extract, %	95.93[a]	95.41[a]	92.62[b]	93.23[b]	0.359	<0.01

[1]Standard error of means
[ab] Means in the same row with different superscripts differ (P < 0.05)

Table 5. Effect of adaptation period on fecal dry matter in cats fed dry feed and canned feed.

Items	Adaptation period				SEM[1]	P-value
	d4	d8	d12	d16		
Canned feed, %	37.99	37.28	44.77	56.07	3.782	0.27
Dry feed, %	50.73^{bc}	47.94^{c}	68.39^{a}	61.47^{ab}	6.528	0.01

[1]Standard error of means

[ab] Means in the same row with different superscripts differ (P < 0.05)

Table 6. Effect of adaptation period on blood profiles in cats fed dry feed and canned feed

Items	Treatment		SEM[1]	P-value
	Canned feed	Dry feed		
Total protein, g/dL	6.60	6.93	0.154	0.30
Albumin, g/dL	2.66	2.81	0.038	0.03
Globulin, g/dL	3.96	4.25	0.189	0.47
BUN, mg/dL	24.36	23.93	0.971	0.83
Creatinine, mg/dL	1.48	1.50	0.053	0.86

[1]Standard error of means

Chapter IV. Effect of Different Levels of Deboned Chicken Meat Inclusion as a Protein Source on Nutrient Digestibility and Blood Profiles in Cats fed Dry Feed

ABSTRACT: A total of 16 cats (seven long hair cats and nine short hair cats) with an average body weight (BW) of 4.79 ± 1.19 kg were used in a 21-day trial to determine the effect of different levels of deboned chicken meat inclusion as a protein source on nutrient digestibility and blood profiles in cats fed dry feed. Cats were allocated completely randomized design (CRD) into four treatments according to BW and type of cats' hair (four replicates with two long hair cats and two short hair cats, one cat per cage). Dietary treatments included: 1) dry feed (basal feed) (Daehan feed company), 2) basal feed + 25% deboned chicken meat of protein source, 3) basal feed + 45% deboned chicken meat of protein source, and 4) basal feed + 70% deboned chicken meat of protein source. Increasing deboned chicken meat inclusion linearly and quadratically increased (P < 0.05) the digestibility of dry matter and crude protein. The digestibility of dry matter and crude protein values were greatest in feed inclusion with 45% deboned chicken meat inclusion. Regression analysis shows that the dry matter digestibility was the greatest at 42.38% deboned chicken meat inclusion of protein source. The digestibility of crude protein was highest at 48.20% deboned chicken meat inclusion of protein source. The digestibility of ether extract reached the highest point of 45.56% deboned chicken meat inclusion of protein source. There was no significant difference observed in total protein, albumin, globulin, BUN, and creatinine levels among four treatments (P > 0.05). In conclusion, our results indicated that inclusion deboned chicken meat as a protein source improved the cats' nutrient digestibility, and the cats' nutrient digestibility reached the highest point of 45% deboned chicken meat inclusion of protein source.

Key words: Blood profiles, cats, nutrient digestibility, protein, deboned chicken meat

1. INTRODUCTION

Cats are recognized to have evolved as obligate carnivores, consuming feeds (small mammals, insects, birds) containing mostly water, protein, and relatively little carbohydrate or fat (Buffington, 2008). The feeding of raw meat-based feed to cats has received increasing attention in recent years. In captivity or in a home setting, a felid's feed is provided solely by the zoo or owner, respectively. For captive exotic felids, the predominant feed types fed are raw meat-based and whole prey feeds. Feeding these feed types is not usual in domestic cats, but there has been an increased popularity in feeding alternative feed types, including raw and whole prey feeds, recently. Much of the

rationale for feeding raw meat and whole prey feeds are based on the cat's evolutionary history as a carnivore (Kerr, 2012). In addition, cats require relatively high amounts of protein, specific amino acids, essential fatty acids, and vitamins that are abundant in animal tissues (MacDonald et al., 1984; Baker and Czarnecki-Maulden, 1991).

Many people who feed raw meat feeds believe that heat processing may decrease some of the nutritional benefits in the feed, including heat-labile nutrients such as thiamin, and potentially destroying functional proteases present in the raw meat (Freeman and Michel, 2001; Berschneider, 2002). Owners who feed raw meat claimed that they improve coat color and quality, increase physical activity levels, improve behavior, improve health and immune function, and reduce incidence of allergies, arthritis, pancreatitis, and parasites (Freeman and Michel, 2001). However, according to Freeman and Michel (2001) raw meat-based feeds had a potential pathogen contamination of the uncooked meat causes health risks to the pet fed the feed as well as to other pets, human family members, and members of the public in contact with the pet.

There is a paucity of peer-reviewed literature examining nutrient composition, apparent total tract macronutrient digestibility, and bioavailability of raw meat-based and whole prey feeds in felids. A majority of research pertaining to raw meat has focused on raw beef- and horsemeat-based feeds, with little research focused on alternative protein sources (Kerr, 2012). Due to the lack of consensus and paucity of good data can make it difficult for veterinarians to provide informed feeding recommendations to dog and cat owners. Therefore, this study was conducted to investigate the effect of different levels of deboned chicken meat inclusion as a protein source on nutrient digestibility and blood profiles in cats.

2. MATERIALS AND METHODS

The experimental protocol used in this study was approved by the (SNUIACUC-160712-22) and complied with the guidelines provided by the Animal Care and Use Committee of Seoul National University. This experiment was carried out at Irion Animal Hospital (445 Dosan-Dong, Gangnam-gu, Seoul, Korea). The cats' health management and basic general experiment management (feeding, taking fecal samples and caring) was carried out by Irion animal hospital veterinarian and their guideline.

2.1 Experimental design, animals and feeds

A total of 16 cats (seven long hair cats and nine short hair cats) with an average body weight (BW) of 4.75 ± 1.19 kg were used in a 21-day trial. Cats were allocated to one of four treatments

using completely randomized design (CRD), according to BW and type of cats' hair. Dietary treatments included: 1) dry feed (basal feed) (Daehan feed company), 2) basal feed + 25% deboned chicken meat, 3) basal feed + 45% deboned chicken meat, and 4) basal feed + 70% deboned chicken meat. All feeds were manufactured through Wenger TT760 Extruder in Daehanfeed. Mechanical deboned chicken meat was used as chicken meat source. Basal feed was ground and mixed and deboned chicken meat inclusion was added directly into pre-conditioner before extruding. All feeds were formulated to meet or exceed NRC (2006) nutrient requirements (Table 1). The daily amount of feed was calculated considering the calories of the feed. Cats were individually housed in stainless-steel cages (0.77×0.51×0.63 m) at the Irion animal hospital (445, Dosan-daero, Gangnam-gu, Seoul, Republic of Korea). Each cage was equipped with a feed dish, water dish that allowed for ad libitum access to water throughout the experiment, fecal box (0.33×0.44×0.16m) and a shelf (0.51×0.29 m). The shelter was installed at 0.3m high from the floor. Lighting was automatically regulated to provide 14 h of fluorescent light with starting at 6 am and 10 h of darkness, supplemented with light infrared lighting by recording web cam. During the adaptation period, sawdust sand was used to put in feces box, and after 5 days' adaptation period, the sawdust sand was replaced by pads. The target room temperature and humidity were $23 \pm 2°C$ and $50 \pm 10\%$, respectively.

Each day, feed was weighted and divided into 2 equal proportions, placed in stainless steel bowls, and left out at 09:00 and 16:00h. Bowls were removed before the next meal, and any remaining feed was weighted and recorded. Water was provided ad libitum. Fecal boxes were cleaned between 08:00 and 09:00h, and between 15:00 and 16:00h, and the amount of feed was fed corresponding to the maintenance energy ($100 \times$ body weight$^{0.67}$) (NRC, 2006). The fresh water was supplied from time to time.

2.2 Sampling and measurements

During the last 5 days (d 17-21) of experimental period, all fresh fecal grab samples were daily collected in each pen to calculate the apparent total tract digestibility for dry matter, crude protein, and ether extract. All feces samples were immediately stored in a zipper bag at $-20°C$ until analysis. At the analysis time, the fecal samples were dried at $60°C$ for 72 h in a drying oven (AMP Daw Model 18, Daehan scientific, Korea) and finely ground to pass through a 1-mm screen (Wiley Mill intermediate, Thomas Scientific).

Before blood collection, cats were feed-deprived overnight and anesthetized with Sevo-flurane gas using a facial mask. Blood samples were collected via jugular venipuncture, transferred to non-heparinized tubes to obtain serum. All samples were centrifuged within 1 h of collection. Serum and plasma tubes were centrifuged ($1,100-1,300 \times g$ for 15 min) at $4°C$. The creatinine concentrations were determined using an Astra-8 Analyzer (Beckman Instruments, Inc., Brea, CA 92621). The blood

urea nitrogen (BUN) and concentrations of albumin, globulin in the serum samples were measured using an automatic blood analyzer (ADVIA 120, Bayer, USA). Serum total protein was determined using an automatic biochemistry analyser (HITACHI 747, Hitachi, Tokyo, Japan).

2.3 Laboratory analysis

Feed samples were dried at 60°C for 72 h, and were finely ground to pass through a 1-mm screen. Samples were analyzed for the moisture content (method 930.15; AOAC 1995), the crude ash content (method 942.05; AOAC 1995), the crude fat content (method 920.39; AOAC 1995), the crude protein content (method 988.05; AOAC 1995), the calcium (method 984.01; AOAC 1995), and phosphorus (method 965.17; AOAC 1995).

2.4 Statistical analysis

The all data were analyzed as a completely randomized design using mixed procedures of SAS (SAS Institute, 2004). Polynomial regression was used to describe the shape of the response to increasing concentration of deboned chicken meat in the feeds. Duncan's multiple range tests with a p < 0.05 indicating significant.

3. RESULTS

Increasing deboned chicken meat inclusion linearly and quadratically increased (P < 0.05) the digestibility of dry matter and crude protein. The digestibility of dry matter and crude protein values were greatest in feed inclusion with 45% deboned chicken meat inclusion. No significant difference was observed in the ether extract among four treatments (P > 0.05).

Regression analysis shows that the dry matter digestibility was the highest at 42.38% inclusion level of deboned chicken of protein source (Figure 2). The digestibility of crude protein was highest at 48.20% inclusion level of deboned chicken meat of protein source (Figure 3). The digestibility of ether extract reached the highest point of 45.56% inclusion level of deboned chicken meat of protein source (Figure 4).

There was no significant difference observed in total protein, albumin, globulin, BUN, and creatinine levels among four treatments (P > 0.05).

4. DISCUSSION

Protein is very essential nutrient for cat's growth, where it is required to maintain the total structure of this animal, which comprises of: muscle, bone, ligaments and tendons. The functional components of the body, including enzymes, plasma, hormones and neuro-transmitter are all protein based on (Peterson, 2011a,b). The high protein requirement of cats has been attributed to the apparent inability of the hepatic ureagenic, gluconeogenic and catabolic enzymes of this species to adapt to dietary protein intake (Rogers et al., 1976; Rogers and Morris, 1980). Previous studies concluded that the hepatic catabolic enzymes of cats seemed to be permanently set to a very high level and failed to adapt to low dietary protein as in other species (Schimke, 1962; Harper, 1965). Rogers et al. (1976) assessed the activity of several amino acid catabolic enzymes in liver biopsies taken from cats fed either low or high protein feeds. Natural cat feed should carry a minimal protein content of 50%-70% (Peterson, 2011b). Others estimated cat protein requirement to be between 50% and 60% (Myrcha and Pinowski, 1970; Vonduruska, 1987; Crissey et al., 1999; Zoran, 2002), since cat is an obligate carnivore, where the main feed is protein domination (Peterson, 2011b). Many veterinarians insisted that the minimal value should be 35-45% for adult cats and more for kittens, the sick and the injured (Shariff et al., 2013).

As similar to the results of current study, previous literature had indicated that raw meat–based feeds had significant higher digestibility of crude protein, energy or dry matter than the extruded feeds (Crissey et al., 1997; Vester et al., 2010a). Likewise, Kerr et al. (2012) reported that apparent total tract DM, CP, fat, and GE digestibility were greater when cats consumed raw beef based feed compared with cats fed extruded feed. The possible reason for improved absorption and digestion of nutrients in the feed with deboned chicken meat inclusion could be due to effective breakdown of dietary high protein in feed with deboned chicken meat inclusion. Besides, in this study, cats fed the feed with 70% deboned chicken meat inclusion (calculated composition: 26% CP; 12.7% crude fat) had a lower digestibility of dry matter compared to cats fed the feed with 50% deboned chicken meat inclusion (calculated composition: 27.9% CP; 9.7% crude fat). To compare with a previous study, Vester et al. (2010b) reported that total tract apparent dry matter digestibility was higher when cats were fed the beef-based feed (57% protein; 28% fat) compared with the horse-based feed (51% protein; 30% fat). However, the reason for this is not clear, and may be a higher 1.9% CP in the feed with 45% deboned chicken meat inclusion than 70% deboned chicken meat inclusion could be a possible reason for the greatest nutrient digestibility in cat fed the feed with 45%. In addition, according to August, (2009) who reported that when fat digestion is incomplete, bacteria in the colon can ferment the undigested fat, producing potent secretagogues and prionflammatory compounds. This results in a secretory diarrhea as well as intestinal inflammation. Therefore, we hypothesis high crude fat in treatment with 70% of raw meant (12.7%) compare to the crude fat in

treatment with 50% of deboned chicken meat inclusion (9.7%) could has a negative effect on nutrient digestibility absorption. However, the reason for this is not clear. Thus further experiments are necessary to find the effects of high fat supplementation on nutrient digestibility in cats.

The blood urea and creatinine values generally assess renal damage in animals and humans. Creatinine and urea both are metabolic wastes that enter into the bloodstream and are discharged out by kidneys. When kidney filtration rate declines, creatinine and urea levels in the blood increase spontaneously (Kaneko, 1989). In the current study, no significant difference was observed in total protein, albumin, globulin, BUN, and creatinine levels among four treatments. However, no comparisons could be made with other studies because there was a scarcity of information on the effects of deboned chicken meat inclusion on blood profiles in cats. Thus further experiments are necessary to find the effects of deboned chicken meat inclusion on blood profiles in cats.

5. CONCLUSION

In conclusion, our study indicated that inclusion the feed with deboned chicken meat inclusion improved the cats' nutrient digestibility, and the cats' nutrient digestibility reached the highest point of 45% deboned chicken meat inclusion. The results of the regression analysis showed that the highest dry matter, crude protein, and ether extract digestibility were 42.38%, 48.20%, and 45.56% of deboned chicken meat inclusion, respectively.

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Table 1. Ingredients and nutritional composition of the experimental feeds

Ingredients	Treatment			
	CON (0%)	Low (25%)	Medium (45%)	High (70%)
Rice	60.09	56.35	47.76	39.81
Beet pulp	4.59	4.33	4.04	3.62
Poultry by-products meal	27.84	24.73	23.62	15.96
Mechanical deboned chicken meat	0.00	8.67	20.22	36.19
Flavor powder	1.38	1.30	1.21	1.09
Flavor liquid	1.84	1.73	1.62	1.45
Poultry fat	2.94	1.53	0.00	0.00
Limestone	0.00	0.08	0.00	0.38
MCP	0.00	0.00	0.01	0.00
Salt	0.00	0.00	0.00	0.01
KCl	0.00	0.00	0.00	0.01
Methionine, 99%	0.27	0.25	0.32	0.22
Lysine, 78.4%	0.00	0.00	0.02	0.11
Tryptophan, 10%	0.00	0.00	0.22	0.24
Taurine, 97%	0.14	0.13	0.12	0.11
Vitamin[1]	0.18	0.17	0.16	0.14
Mineral[2]	0.09	0.09	0.08	0.07
Choline, 50%	0.54	0.54	0.50	0.53
Calculated composition, %				
Moisture	3.6	3.5	4.2	5.2
Crude protein	26.0	26.0	27.9	26.0
Crude ash	5.7	5.6	5.7	5.5
Crude fat	9.0	9.0	9.7	12.7
Calcium	1.01	1.00	1.00	1.00
Total phosphorus	0.99	0.97	1.00	0.88
Crude fiber	1.7	1.8	1.8	1.8

[1]) One kilogram of the vitamin mixture contained 11,000,000 IU of vitamin A, 650,000 IU of vitamin D, 75,000 IU of vitamin E, 2.5 g of vitamin B1, 5.5 g of vitamin B2, 5.0 g of vitamin B6, 300 mg of folic acid, 25 g of niacin.

[2]) One kilogram of the mineral mixture contained 110g of Fe, 13 g of Cu, 150 g of Zn, 30 g of Mn, 0.5 g of Co, 2.5 g of I, 350 mg of Se.

Table 2. Effect of different levels of deboned chicken meat inclusion as a protein source on nutrient digestibility in cats fed dry feed

Items	Treatment				SEM	P-value	
	CON (0%)	Low (25%)	Medium (45%)	High (70%)		Linear	Quadratic
Dry matter, %	70.19	74.98	80.58	74.71	1.248	0.03	0.01
Crude protein, %	55.40	64.08	74.65	67.5	2.137	<0.01	0.01
Ether extract, %	85.78	88.14	91.13	88.84	0.875	0.52	0.22

[1]Standard error of means

Table 3. Effect of different levels of deboned chicken meat inclusion as a protein source on blood profiles in cats fed dry feed

Items	Treatment				SEM[1]	P-value
	CON (0%)	Low (25%)	Medium (45%)	High (70%)		
Total protein, g/dL	6.60	6.97	6.77	7.30	0.167	0.53
Albumin, g/dL	2.87	2.77	2.75	2.60	0.042	0.14
Globulin, g/dL	3.72	4.20	4.02	4.70	0.185	0.32
BUN, mg/dL	24.60	20.65	21.07	19.52	0.985	0.32
Creatinine, mg	1.32	1.82	1.52	1.47	0.099	0.37

[1]Standard error of means

Figure 1. Digestibility of dry matter with inclusion level of deboned chicken meat as a protein source in cats feed
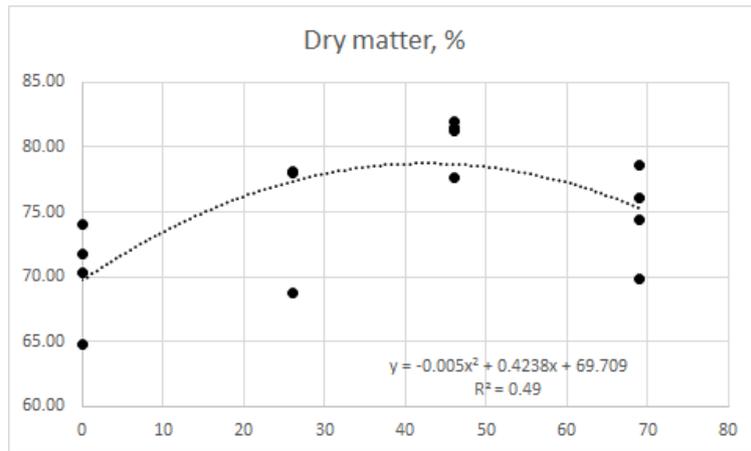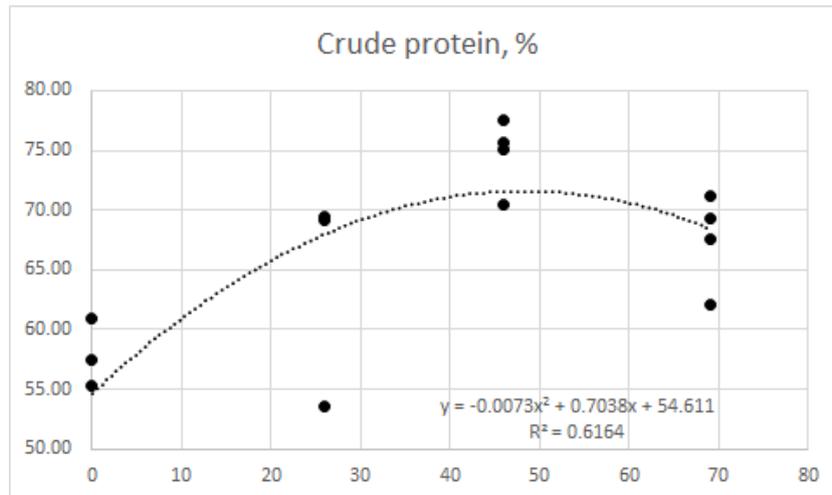
Figure 2. Digestibility of crude protein with inclusion level of deboned chicken meat as a protein source in cats feed

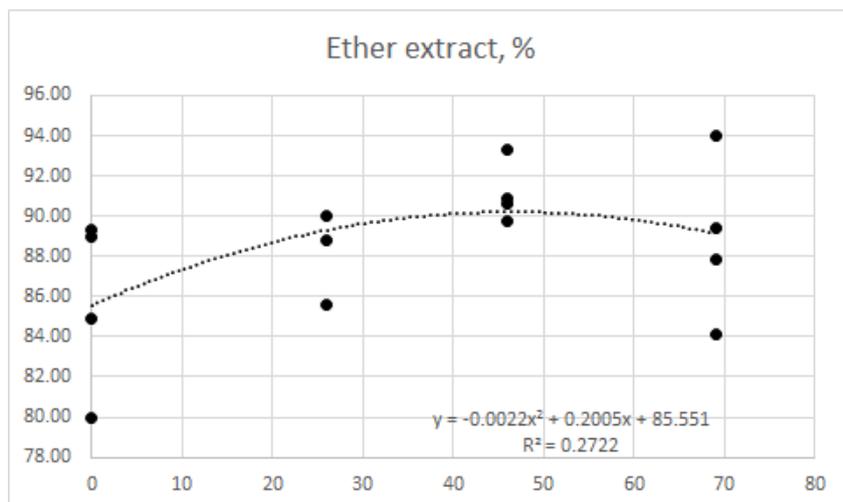**Figure 3. Digestibility of ether extract with inclusion level of deboned chicken meat as a protein source in cats feed**

The chart title reads "Ether extract, %" with the trendline equation $y = -0.0022x^2 + 0.2005x + 85.551$ and $R^2 = 0.2722$.

Chapter V. Effect of Environmental Housing Conditions on Nutrient Digestibility and Stress Response in Cats

ABSTRACT: A total of 12 cats (six long hair cats and six short hair cats) with an average body weight (BW) of 4.30 ± 0.85 kg were used in a 21-day trial to determine the effect of environmental housing conditions nutrient digestibility and stress response in cats. Cats were allocated completely randomized design (CRD) into two different breeding environments treatments according to BW and type of cats' hair (six replicates with three long hair cats and three short hair cats, one cat per cage). Treatments included: 1) Cats in the small cage were housed singly in stainless-steel cages measuring 0.77 × 0.51 × 0.63 m (length × breadth × height) and 2) Cats in the large room were housed singly in wooden wall room measuring 1.2 × 1.5 × 2.5 m (length × breadth × height). During d 13 − 16, the digestibility of crude protein significantly increased in cats housed in the large compared to cats housed in the small cage. Cat housed in the large room tend to increase the digestibility of dry matter (P = 0.09). However, the difference housing conditions did not affect no the digestibility of dry matter, crude protein, crude ash, and ether extract between two treatments during d 17 − 20 (P > 0.05). No significant difference was observed in the cortisol levels between two treatments on the initial day, d 7, and d 21 of experiment. During d 8 − 21, cats housed in large room had a lower stress response than cats housed in small cage (P < 0.05). There was no significant difference observed on the stress levels in cats housed in small cage in different experimental periods. In conclusion, cats housed in the large room improved the digestibility of dry matter and crude protein during d 13 − 16 and decreased the tress levels compared to cats housed in the small cage treatment. No significant difference was observed in the cortisol levels between two treatments.

Key words: cats, cortisol, environmental housing conditions, nutrient digestibility, stress

1. INTRODUCTION

The popularity of the domestic cat as a pet has increased steadily in the past few years. Thereby, in recent years, research has been carried out on the behavior and welfare of cats kept in different environments such as laboratories, animal shelters, quarantine and boarding catteries, and the home. According to Zoran and Buffington (2011) reported that within an enclosure (the internal environment), there should be adequate separation between feeding, resting and elimination (litter tray) areas. The enclosure should be large enough to allow cats to express a range of normal behaviors, and to permit the caretaker or owner to carry out cleaning procedures easily. When a cat is confined in a

novel environment, such as an animal shelter, it can be stressful (McCobb et al., 2005) and some of this stress is likely to be due to confinement in a single cage (Cauvin et al., 2003). In animal shelters, in particular, the stress of confinement might be associated with an increased risk of disease conditions, such as those affecting the respiratory and urinary tracts (Westropp et al., 2006; Dinnage et al., 2009; Tanaka et al., 2012). It was reported that the home range of free-living domestic cats varies between $200m^2$ and $1.7km^2$ (Liberg and Sandell, 1988; Bradshaw, 1992). A temporary stay in an animal shelter or boarding cattery, therefore, presents far more restricted living conditions than those experienced in a free-ranging territory or a private home. Roy (1992) studied spatial factors influencing the welfare of cats in shelters, and recommended the provision of hides as well as elevated shelves made of wood. In parallel, many welfare issues are associated with this type of management. Problems include anxiety and fear, and various stress-related changes in behaviour including aggressive and destructive behavior, hyper-vigilance causing fatigue, pica (eating inedible things), excessive grooming and vocalizing, self-mutilation, and suppression of feeding, elimination, grooming, exploration and play (Kessler and Turner, 1999; Casey and Bradshaw, 2005). Besides, Mertz (2013) showed that during rats become stressed, alterations in motility of the gut occur. The upper gut, including the stomach and small intestine, exhibits markedly reduced transit time. This may be a defense mechanism to promote vomiting and reduce oral intake. Conversely the large bowel motility increases with increased stool output and transit speed. In addition, there are no clear guidelines on the minimum space required and optimum group density in boarding catteries and animal shelters. Therefore, we hypothesized that cats caged in small cage could result in increasing the stress which has a negative effect on digestibility of cats. Therefore, this study was conducted to determine effect of environmental housing conditions on nutrient digestibility and stress response in cats.

2. MATERIALS AND METHODS

The experimental protocol used in this study was approved by the (SNUIACUC-160712-22) and complied with the guidelines provided by the Animal Care and Use Committee of Seoul National University. This experiment was carried out at Irion Animal Hospital (445 Dosan-Dong, Gangnam-gu, Seoul, Korea). The cats' health management and basic general experiment management (feeding, taking fecal samples and caring) was carried out by Irion animal hospital veterinarian and their guideline.

2.1 Experimental design, animals and feeds

A total of 12 cats (six long hair cats and six short hair cats) with an average body weight (BW) of 4.30 ± 0.85 kg were used in a 21-day trial. Cats were allocated completely randomized design (CRD) into two different housing environments treatments according to BW and type of cats' hair (six replicates with three long hair cats and three short hair cats, one cat per cage). Treatments included: 1) Cats in the small cage treatment were housed singly in stainless-steel cages measuring 0.77 × 0.51 × 0.63 m (length × breadth × height) with a feed dish, a water dish and a fecal box (0.33×0.44×0.16m) where cat excretes their excreta, and a shelf (0.51×0.29m), which was placed at 0.3m high from the floor (figure 1); 2) Cats in large room treatment were housed singly in wooden wall room measuring 1.2 × 1.5 × 2.5 m (length × breadth × height) with a feed dish, a water dish, a fecal box (0.33×0.44×0.16m) where cat excretes their excreta, a shelter, and three shelves (0.51×0.29m), which was placed at 0.3m, 0.7m, and 1.5m high from the floor (figure 2). Cats were provided commercial feed (Daehan feed company). All feeds were formulated to meet or exceed NRC (2006) nutrient requirements (Table 1). The daily amount of feed was calculated considering the calories of experimental feed. Lighting was automatically regulated to provide 14 h of fluorescent light with starting at 6 am and 10 h of darkness, supplemented with light infrared lighting by recording web cam. During the adaptation period, sawdust sand was used to put in fecal box, and after 5 days of adaptation period, the sawdust sand was replaced by pads. The target room temperature and humidity were 23 ± 2°C and 50 ± 10%, respectively.

Each day, feed was weighted, placed in stainless steel bowls, and left out at 09:00 and 16:00h. Bowls were removed before the next meal, and any remaining feed was weighted and recorded. Water was provided ad libitum. Fecal boxes were cleaned between 08:00 and 09:00h, and between 15:00 and 16:00h, and the amount of feed was fed to the amount corresponding to the maintenance energy ($100 \times$ body weight$^{0.67}$) (NRC, 2006) of cats. The fresh water was supplied from time to time.

Figure 1. Small cage (0.77×0.51×0.63 m)

Figure 2. Large room (1.20×1.50×2.50 m)

2.2 Sampling and measurements

After 12 days of adaptation period, all fresh fecal grabed samples were daily collected in each pen to calculate the apparent total tract digestibility of dry matter, crude protein, and ether extract (during d 13 – 16, and d 17 – 20). All feces samples were immediately stored in a zipper bag at −20°C until analysis. At the analysis time, the fecal samples were dried at 60°C for 72 h in a drying oven (AMP Daw Model 18, Daihan scientific, Korea) and finely ground to pass through a 1-mm screen (Wiley Mill intermediate, Thomas Scientific).

Before blood collection, cats were feed-deprived overnight and anesthetized with Sevo-flurane gas using a facial mask. Blood samples were collected via jugular venipuncture, transferred to non-heparinized tubes to obtain serum on initial day, day 7 and day 21 by veterinarians at Irion Animal Hospital. All samples were centrifuged within 1 h of collection. Serum and plasma tubes were centrifuged (1,100-1,300 × g for 15 min) at 4°C. Serum cortisol was analyzed using nephelometry to determine the cat's stress index according to the experimental environment (Dade Behring, Marburg, Germany).

Cameras were installed to investigate the effects of cats' stress on the cats' behaviour according to the experimental housing. Video recording was performed through a webcam capable of

recording 24 hours in order to measure the behaviour score. A webcam (Xiaoyi smart web-cam®, Shanghai Xiaoyi Technology Co., China) was used. The photographing time was 24 hours on day 7 after the start of the experiment and at the end of the adaptation period and the adaptation period. During the video analysis, a cat behaviour observation chart was prepared and data were collected. The cats' behaviour observation index was referenced to Eckstein and Hart, (2002) and McCobb et al. (2005).

2.3 Laboratory analysis

Feed samples were dried at 60°C for 72 h, and were finely ground to pass through a 1-mm screen. Samples were analyzed for the moisture content (method 930.15; AOAC 1995), the crude ash content (method 942.05; AOAC 1995), the crude fat content (method 920.39; AOAC 1995), the crude protein content (method 988.05; AOAC 1995), the calcium (method 984.01; AOAC 1995), and phosphorus (method 965.17; AOAC 1995).

2.4 Statistical analysis

All data were analyzed by the student's t-test (SAS Institute, 2009), and a main effect in the statistical model was housing (large room or small cage), with each cat as the experimental unit. The differences between means were assessed using Fisher's LSD procedure. A probability of $P < 0.05$ was accepted as statistically significant and highly significant at $P < 0.01$. Reported pooled SEM was determined according to the Student's t-test procedure of SAS. Probability level of less than 0.1 was considered tendency.

3. RESULTS

In the current study, during d 13 – 16, cats housed in the large room treatment had a greater the digestibility of crude protein than cats housed in the small cage treatment ($P < 0.05$) (Table 2). Trends in increased the digestibility of dry matter ($P = 0.09$) were observed in cats housed in the large room treatment. However, no significant difference ($P > 0.05$) was observed in the digestibility of dry matter, crude protein, crude ash, and ether extract between two treatments during d 17 – 20.

Tendencies in decreased the cortisol level as experimental period were observed in cats housed in small cage ($P = 0.09$) and large room ($P = 0.10$) (Table 3).

Cats housed in the large room had a lower stress response than cats housed in the small cage on d 0 and during d 8 – 21 adaptation period ($P < 0.01$) (Table 4). The stress response significant

decreased during d 8 − 21 adaptation period compared to the adaptation period of cat during d 1 − 7 when cats housed in the large room (Table 5). However, no significant difference was observed three adaptation periods when cats housed in small cage.

4. DISCUSSION

When a cat is confined in a new environment, such as an animal shelter, it can be stressful (McCobb et al., 2005). Stress could be a reason to lead to nonspecific clinical and behavioral signs that include variable combinations of vomiting, diarrhea, anorexia or decreased feed and water intake, fever, lethargy, somnolence, enhanced pain-like behaviors, and decreased general activity which could have a negative effect on nutrient digestibility in cats. Therefore, it is important that they are provided with suitable housing conditions, which aim to minimize exposure to stress in order to maximize welfare (Finka et al., 2014).

In the current study, during d 13 − 16, cats housed in the large room treatment had a higher digestibility of crude protein than cats housed in the small cage treatment ($P < 0.05$). A slight increase the digestibility of dry matter ($P = 0.09$) was observed in cats housed in the large room treatment. In addition, the results showed that the levels of stress decreased in cats housed in large room but no significant difference was observed in cats housed in small cage. Similar results were also reported by Kessler, (1999), who shown that boarding cat housed in single cage with a floor area of 1.0 m^2 had significantly lower stress levels than animals in cages with a floor area of 0.7m^2. In this study, cats in the large room were also needed a hide box, elevated shelves made of wood, and adequate height, those items are recommended by Roy (1992) and Rochlitz, (1999). Furthermore, Rochlitz (1999) reported that resting areas where cats can be retreated and be concealed are required in addition to 'open' resting areas (e.g. shelves), are essential for their well-being. These above mentions, which the large room in our study was also provided, and this could be possible reasons to explain the reduction of stress levels in cats housed in the large room that eventually enhance their welfare, increased nutrient digestibility when cats housed in large room in this study.

Cortisol is a glucocorticoid hormone synthesized from cholesterol by enzymes of the cytochrome P450 family in the zona fasciculate, the middle area of the adrenal cortex (Randall, 2010). Regulated via the Hypothalamic-pituitary-adrenal axis, cortisol is the primary hormone responsible for the stress response. When the body is stressed, the hypothalamus signals the autonomic nervous system and the pituitary gland and the process is started to produce epinephrine and cortisol, sometimes called the "stress hormones." However, no significant difference was observed in the cortisol levels between two treatments, but the cortisol was slightly lower in cats housed in large room treatment than cats in cage treatment that could be a possible reason for alleviating the stress in cats

housed in large room eventually improved the digestibility of dry matter and crude protein in this study.

5. CONCLUSION

In conclusion, the current study indicated that cats housed in the large room improved the digestibility of dry matter and crude protein during d 13 - 16 and decreased the levels of stress compared to cats housed in the small cage. However, no significant difference was observed in the cortisol levels between two treatments at initial, d 7, and d 21 experimental periods.

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Table 1. Analyzed composition of experimental feed (%)

Items	Feed
Moisture	6.47
Crude protein	33.01
Crude ash	7.65
Crude fat	15.40
Crude fiber	3.59
Calcium	1.33
Total phosphorus	0.89

Table 2. Effect of environmental housing conditions on nutrient digestibility in cats

Items	Treatment		SEM[1]	P-value
	Small cage	Large room		
d 13 - 16				
Dry matter, %	67.02	74.54	2.233	0.09
Crude protein, %	62.92	74.38	2.671	0.02
Crude ash, %	10.46	12.79	5.142	0.84
Ether extract, %	92.54	94.92	1.256	0.38
d 17 - 20				
Dry matter, %	74.79	73.76	1.712	0.78
Crude protein, %	71.51	72.79	1.905	0.75
Crude ash, %	14.81	15.47	6.197	0.96
Ether extract, %	94.93	96.11	0.732	0.45

[1]Standard error of means

Table 3. Effect of environmental housing conditions on cortisol levels of blood in cats

Items	Initial (d 0)	Adaptation (d 7)	Final (d 21)	SEM[1]	P-value
Large room	1.81	1.10	1.50	0.139	0.10
Small cage	3.76	1.28	1.80	0.499	0.09

[1]Standard error of means

Table 4. Effect of environmental housing conditions on stress response in cats

Items	Treatment		SEM[1]	P-value
	Small cage	Large room		
d 0	2.38	1.41	0.177	<0.01
d 1 – 7	2.10	1.58	0.138	0.08
d 8 – 21	2.09	1.19	0.163	<0.01

[1]Standard error of means

Table 5. Effect of environmental housing conditions on stress response in different adaptation periods in cats

Items	d 0	d 1 – 7	d 8 – 21	SEM[1]	P-value
Large room	1.41^{ab}	1.58^a	1.19^b	0.065	0.03
Small cage	2.38	2.10	2.09	0.089	0.35

[1] Standard error of means

[ab] Means in the same row with the different superscripts differ (P < 0.05)

Chapter VI. Overall Conclusion

The overall objective of this study was to evaluate different type of feed, different levels of deboned chicken meat inclusion in dry cat feed, and environmental housing conditions influenced on adaptation time, stress, and nutrient digestibility in cats.

The first experiment, presented in Chapter III, was to evaluate the effect of adaptation period on nutrient digestibility and blood profiles in cats fed dry feed and canned feed. The results suggested that the cats' digestibility after 16 days of adaptation might be reliable when cats were fed canned feed. However, when cat fed dry feed, the cats' digestibility is highly reliable after 12 days of adaptation period because no significant difference was observed in nutrient digestibility after 12 days of adaptation period. In addition, the albumin levels were higher in cats fed dry feed than that of cats fed canned feed.

The second experiment, presented in Chapter IV, was to evaluate the effect of different levels of deboned chicken meat inclusion as a protein source on nutrient digestibility and blood profiles in cats fed dry feed. The results indicated that inclusion the feed with deboned chicken meat inclusion improved the cats' nutrient digestibility, and the cats' nutrient digestibility reached the highest point of 45% deboned chicken meat inclusion of protein source. The results of the regression analysis showed that the highest dry matter, crude protein, and ether extract digestibility were 42.38%, 48.20%, and 45.56% deboned chicken meat inclusion of protein source, respectively.

The third experiment, presented in Chapters V, was to determine the effect of environmental housing conditions on nutrient digestibility and stress response in cats. The results indicated that cats housed in the large room improved the digestibility of dry matter and crude protein compared to cats housed in the small cage during d 13 - 16. However, no significant difference was observed in the cortisol levels between two treatments on the initial day, day 7, and day 21 of experiment.

Overall conclusion, this research shown that the digestibility is highly reliable in cat fed dry feed with after 12 days of adaptation period. Inclusion the feed with deboned chicken meat inclusion linearly and quadratically improved the cats' nutrient digestibility with the highest point of 45% deboned chicken meat inclusion. In addition, cats housed in the large room improved the digestibility of dry matter and crude protein compared to cats housed in the small cage.

Chapter VII.   Summary in Korean

본 학위논문에서는 동물복지를 고려한 고양이 소화율 시험모델 연구를 위하여 총 3개의 실험이 진행되었다. 첫째로는 건사료와 캔사료 급여에 따른 고양이의 소화율실험 적응기간 검증을 수행하였으며, 둘째로는. 고양이용 건사료의 단백질 공급원으로 생닭고기와 계육분의 소화율 차이와 최적비율을 조사 하였다. 마지막으로는 실험환경 조건이 고양이의 스트레스 및 소화율에 미치는 영향을 조사하였다.

실험 1: 건사료와 캔사료 급여에 따른 고양이의 소화율 실험 적응기간 검증

건사료와 캔사료 급여에 따른 고양이의 소화율실험 적응기간 검증을 위하여 평균체중 4.30 ± 1.05 kg의 고양이 12마리를 공시하였으며, 4마리의 장모종 고양이와 8마리의 단모종 고양이를 대상으로 실험을 진행하였다. 실험처리구는 캔사료를 급여한 캔사료 처리구와 건사료를 급여한 건사료 처리구로 구성하였다. 소화율 측정을 위한 케이지에서의 고양이의 소화율 적응기간으로는 0-4일, 5-8일, 9-12일, 13-16일로 나누어서 케이지 적응기간별 영양소소화율을 비교검증 하고자 하였다. 적응기간별 캔사료 및 건사료의 영양소소화율을 측정한 결과, 적응기 4일 후에 건물소화율은 캔사료의 소화율이 높게 나타났지만(P=0.02), 조단백질 소화율은 건사료의 소화율이 높게 나타났다 (P=0.03). 적응기를 8일 가진 후에는 건물소화율에서는 캔사료의 소화율이 높게 나타났으나 (P=0.04), 조단백질 소화율에서는 건사료의 소화율이 높게 나타났다 (P=0.03). 적응기 12일 후 건물소화율에서는 캔사료를 급여한 고양이의 소화율이 유의적으로 높았으며 (P<0.01), 조단백질 소화율에서는 건사료를 급여한 고양이의 소화율이 유의적으로 높았다 (P=0.02). 적응기 16일 후에는 고양이의 조단백질 소화율에서는 건사료의 소화율이 캔사료보다 높은 결과를 나타냈다 (P<0.01). 캔사료의 적응기간별 소화율을 비교해 보았을 때, 건물소화율에서는 16일의 소화율에서는 적응기 4일 및 8일과 유의적인 차이가 나타났으며(P=0.03), 조단백질 소화율에서도 적응기 4일, 8일 12일간의 유의적인 차이가 나지 않았지만 적응기 16일의 소화율에서는 적응기 4일과 8일과 유의적인 차이가 나타났다(P=0.01). 건사료의 적응기간별 소화율을 비교해 보았을 때 (표 6), 건물, 조단백질, 조회분, 조지방 소화율에서 적응기 4일, 8일간의 유의적인 차이가 나지 않았지만 적응기 12일과 16일의 소화율에서는 적응기 4일과 8일과 유의적인 차이가 나타났다 (P<0.01). 결론적으로 캔사료를 대상으로 고양이의 영양소 소화율을 측정하고자 할 때 적응기를 16일간 가진 후에 소화율 실험을 수행하는 것이 신뢰도가 높으며, 건사료를 대상으로 고양이 영양소소화율 실험수행을 위해서는 적응기를 12일만 가지고 수행하여도 신뢰도 있는 결과값을 가질 수 있다.

실험 2: 고양이용 건사료의 단백질 공급원으로 생닭고기와 계육분의 소화율 차이와 최적 비율 조사

고양이 건사료내 단백질원료 중 생육의 첨가수준에 따른 영양소 소화율 평가하기 위하여 평균체중 4.75 ± 1.19 kg의 고양이 16마리를 공시하였으며, 7마리의 장모종 고양이와 9마리의 단모종 고양이를 대상으로 실험을 진행하였다. 실험처리구는 건사료내 단백질원료 중 생육의 첨가수준을 0%, 26%, 46%, 69%로 설정하여 처리구를 설계하였으며, 소화율 측정을 위한 케이지에서의 고양이의 소화율 적응기간으로는 0-16일간으로 설정하여 적응기를 가졌으며 이후 17일째부터 21일까지를 5일동안을 본 소화율 측정일로 정하여 분변을 채취하였다. 건물소화율에서는 생육함량이 49%인 처리구의 건물소화율이 다른 처리구들에 비해 가장 높게 나타났다 (P=0.01). 조단백질 소화율에서는 49%처리구와 69%처리구의 소화율이 0%처리구에 비해 유의적으로 높았으며, 49%처리구가 수치적으로 가장 높은 소화율을 나타내었다 (P<0.01). 결론적으로 생육의 함량이 46%인 처리구의 건물소화율 및 조단백질 소화율이 다른 처리구들에 비해 유의적으로 높게 나타났으며, 회귀분석의 결과로 보았을 때 생육 45% 함량이 가장 높은 영양소 소화율을 가질 것으로 예상된다.

실험 3: 실험환경 조건이 고양이의 스트레스 및 소화율에 미치는 영향

소화율 실험환경 조건이 고양이의 스트레스 및 영양소 소화율에 미치는 영향을 조사하기 위하여 평균체중 4.30 ± 0.85 kg의 고양이 12마리를 공시하였으며, 6마리의 장모종 고양이와 6마리의 단모종 고양이를 대상으로 실험을 진행하였다. 실험처리구는 넓은 사육환경(고양이 호텔)과 좁은 사육환경(대사 케이지)로 설정하여 처리구를 설계하였다. 소화율 측정을 위한 케이지에서의 고양이의 소화율 적응기간으로는 12일간으로 설정하여 적응기를 가졌으며 이후 13일째부터 16일까지와 17일째부터 20일째까지 각각 4일동안을 본 소화율 측정일로 정하여 분변을 채취하였다. 영양소 소화율을 측정한 결과, 상대적으로 넓고 좋은 환경인 고양이호텔에서 생활하는 고양이의 영양소 소화율 중 건물소화율과 조단백질 소화율이 유의적으로 높게 나타났으며 (P=0.09, P=0.02), 조회분과 조지방의 소화율에서는 유의적인 차이는 나타나지 않았으나 수치적으로는 고양이호텔에서 생활하는 고양이의 소화율이 높게 나타났다. 17일에서 20일까지의 고양이의 영양소 소화율을 측정한 결과에서는 사육환경에 따른 유의적인 차이는 나타나지 않았다. 고양이의 사육기간에 따른 혈중 cortisol 농도를 측정 소화율을 측정한 결과에서는 사육환경에 따른 유의적인 차이는 나타나지 않았으나, 처음 고양이를 대사케이지에서 생활하게 하였을 때 고양이호텔에 비해 수치적으로 높은 혈중 cortisol 농도를 나타났으며 (Initial, 0 day), 7일째와 21일째의 혈중 cortisol 농도를 측정하였을 때에도 대사케이지에서 생활하는 고양이의 혈중 cortisol 농도가 수치적으로 높게 나타났다. 결론적으로 고양이호텔에서 생활하

는 고양이는 대사케이지에 비해 스트레스를 적게 받아서 더 높은 영양소소화율을 나타내
지만, 적응기간이 경과함에 따라 스트레스 지수 및 영양소 소화율에는 차이가 없어지는
것으로 사료된다.

Chapter VIII.   Overall Summary in Korean

본 학위논문에서는 동물복지를 고려한 고양이 소화율 시험모델 연구를 위하여 총 3개의 실험이 진행되었다

연구 1은 건사료와 캔사료 급여에 따른 고양이의 소화율실험 적응기간 검증을 위하여 사양시험을 진행하였다. 캔사료를 대상으로 고양이의 영양소소화율을 측정하고자 할 때, 적응기를 16일간 가진후에 소화율 실험을 수행하는 것이 고양이의 영양소소화율 결과에 신뢰도가 높을 것으로 사료되며, 건사료를 대상을 고양이의 영양소소화율을 측정하고자 할 때, 적응기를 12일을 가진 후에 소화율 실험을 수행하여도 적응기 16일을 가진 고양이의 소화율과 통계적 유의차가 나타나지 않았기 때문에 건사료를 대상으로 고양이 영양소소화율 실험수행을 위해서는 적응기를 12일만 가지고 수행하여도 신뢰성 있는 결과값을 가질 수 있을 것이다.

연구 2는 고양이 건사료내 단백질원료 중 생육의 첨가수준에 따른 영양소 소화율 평가하기 위하여 사양시험을 진행하였다. 사료 내 단백질원료 중 생육의 함량의 첨가수준이 고양이의 영양소소화율에 미치는 영향을 조사한 결과, 생육의 함량이 46%인 처리구의 건물소화율 및 조단백질 소화율이 다른 처리구들에 비해 유의적으로 높게 나타났으며, 회귀분석을 통한 분석값으로는 42%의 생육함량이 가장 높은 건물 소화율을, 48%의 생육함량이 가장 높은 조단백질 소화율을, 45%의 생육함량이 가장 높은 조지방 소화율을 가지는 것으로 나타났으며, 종합적으로 보았을 때 45%의 생육함량이 가장 높은 영양소 소화율을 가지는 것으로 예상된다.

연구 3은 소화율 실험환경 조건이 고양이의 스트레스 및 영양소 소화율에 미치는 영향을 조사하기 위하여 사양시험을 진행하였다. 고양이의 사육환경에 따른 영양소 소화율의 차이를 조사한 결과 적응후 13-16일째의 영양소 소화율에서는 호텔에서 생활하는 고양이의 건물 및 조단백질 소화율이 대사케이지에서 생활하는 고양이보다 높았으며, 적응후 17-20일째의 영양소 소화율에서는 유의적인 차이가 나타나지 않았다. 혈중 cortisol 농도를 측정한 결과, 고양이 호텔과 대사케이지간의 유의적인 차이는 나타나지 않았으나, 고양이호텔에서 생활하는 고양이의 혈중 cortisol농도가 수치적으로 높게 나타났으며, 적응기간이 지날수록 그 차이는 점차 줄어드는 것을 확인할 수 있었다. 결론적으로 고양이호텔에서 생활하는 고양이는 대사케이지에 비해 스트레스를 적게 받아서 더 높은 영양소소화율을 나타내지만, 적응기간이 경과함에 따라 스트레스 지수 및 영양소 소화율에는 차이가 없어지는 것으로 사료된다.