# CHAPTER I
# INTRODUCTION

## 1.1 Introduction

The International Feed Industry Federation (IFIF) reports that the world population will exceed 10 billion by 2050 (Statistics). By then, the increased population will consume twice as much animal protein as it does today; between 2010 and 2050, consumption of pork and poultry is expected to grow by 105% and 173%, respectively (McLeod, 2011; Tiengtam et al., 2017), which will create enormous challenges in the production of protein feed ingredients, estimated as being more than 1.3 billion tons of dry matter (Paengkoum et al., 2017). Soy grains and some oilseed cakes (e.g., soybean meal, rapeseed meal, and cottonseed meal), and some algal biomass are currently the main sources of protein for ruminants and monogastric animals (Kaewwongsa et al., 2011). Global livestock feed production was estimated to be 1.104 billion tons in 2018 alone, with a total value of more than USD 400 billion (Parisi et al., 2020). Protein is the most costly and restrictive ingredient in feed formulations, and the price of traditional sources of protein has risen significantly due to yield factors and competition between humans and animals (Parisi et al., 2020; Van Huis and Oonincx, 2017). To meet the demand for highly nutritious animal food, the future will drive animal production systems to find new sources of high-quality and sustainable protein-fed raw materials. Economic and environmental concerns must be considered in this context, while competition with plant-based human and animal food chains is reduced (Allegretti et al., 2018; Dicke, 2018). Therefore, urea can be added as a protein source in ruminant diets to improve their growth performance and milk production performance (Paengkoum et al., 2006; Vorlaphim et al., 2021; Wanapat et al., 2000). However, in monogastric species, ammonia concentrations in the gastrointestinal tract and the environment can cause damage to the gastrointestinal mucosa, resulting in impaired nutrient absorption, energy inefficiency, and reduced growth performance (Patra and Aschenbach, 2018). Thence, people have turned their attention to insects with high protein content.

As protein raw materials, insects such as BSF, mealworm larvae (*Tenebrio molitor L.*), and crickets (*Orthoptera: Gryllidae*) are the focus of emerging research fronts and are already used as alternative nutrient sources for poultry and swine feed because they contain nearly 100 percent of the edible portion of protein (Gasco et al., 2019; Oonincx and De Boer, 2012). The feed conversion rate of BSF is better than that of mealworms and crickets, and its survival rate and nitrogen and phosphorus composition do not change greatly with a change in diet (Oonincx et al., 2015). BSF are characterized by a high food conversion rate, short reproductive cycle, and high content of fat, protein, minerals, and vitamins (El-Hack et al., 2020; Spranghers Ottoboni et al., 2017). They are also highly sustainable as they can be raised on a large scale in organic streams, and at a much lower environmental cost than traditional protein sources (Meneguz Schiavone et al., 2018). Multiple studies have shown that BSF can be used as a food or feed source, ultimately helping to solve the global food problem. However, consumers prefer to use BSF in animal feed rather than directly for human consumption, because people have a certain degree of psychological aversion to eating insects (Bukkens, 1997; Nyakeri et al., 2017; Tabata et al., 2017b). Diets supplemented with BSF appear to improve growth performance and digestibility in pigs and poultry compared to other protein feeds (Veldkamp and Bosch, 2015; Zuki et al., 2021). (Schiavone et al., 2018) used whole-fat BSF to replace 50% or 100% soybean oil, and the results showed that the growth performance, blood biochemical immune parameters, and intestinal health of broilers were not impaired. BSF can also reduce the quality and nutrient content of pig manure with an efficiency similar to that of poultry manure, which is beneficial for improving farm hygiene (Nguyen et al., 2015; Zhou et al., 2013), reducing pest numbers, and reducing nutrient pollution in runoff (Mallin and Cahoon, 2003). An *in vitro* study found that BSF reduced CH4 emissions (A Jayanegara et al., 2017). Another *in vitro* study was also found by (Kahraman et al., 2023a) that BSF improved the digestibility of DM and NDF in dairy cows. However, the current research on BSF in goats has not been found. Therefore, the purpose of this study is to:

1) Evaluate the effects of supplementing different levels of BSF on the growth performance, digestibility, antioxidant, and rumen microorganisms of goats.

2) Evaluate the Effects of heat treatment on rumen degradability and protein intestinal digestibility of BSF.

3) Evaluate the effects of heat-treated BSF on goat growth performance, digestion, meat quality, rumen microorganisms, blood immunity, and antioxidant and related gene expression.

## 1.2 Research purposes

1.2.1 To Investigate the effects of different levels of BSF on the growth performance, blood antioxidant capacity, and rumen microbiota of goats.

1.2.2 To Investigate the effects of heat-treated BSF as a bypass protein on rumen degradation and small intestine digestibility rate in goats.

1.2.3 To Investigate the effects of heat-treated BSF as a bypass protein on the growth performance, rumen microbiota, and meat quality of goats.

## 1.3 Research hypothesis

1.3.1 Different levels of BSF can promote or have no effects negative on growth performance blood antioxidant capacity, and rumen microbiota of goats.

1.3.2 Heat treatment of BSF can increase bypass protein, and improve goat growth performance, rumen microorganisms, and meat quality.

## 1.4 Scope and limitations of the study

1.4.1 The experiment was conducted on Xishui Fuxing Animal Husbandry Co., Ltd. (China) and SUT's farm.

1.4.2 Nubian goats and Qianbei goats were used in this study.

1.4.3 The BSF from Henan Province, China, was used in this study.

## 1.5 Expected results

1.5.1 BSF enhances the growth performance, blood antioxidant capacity, and rumen microbiota abundance of goats, and 15% of BSF can still be supplemented in the daily diet of goats.

1.5.2 Heat-treated BSF increases rumen bypass protein, promotes the growth performance of goats, enhances rumen microbiota abundance, and improves meat quality, contributing to a new processing method for the application of BSF in ruminant animals.

## 1.6 References


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