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Bio-potency of Selenium and Protein supplements on reproductive traits of Male Rabbits: A Review

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The inclusion of both micro and macro nutrients has been investigated in the field of animal production and research, expressing promising effects. Perhaps incorporation of both dietary Selenium and Protein at approapriate levels has presented a tremendous impact on productive and reproductive performance of livestock, particularly in tropical environments. However the efficiency of growth and normal physiological functions depends on composition and bioavailability of these nutrients in the diets. These effects could be mediated via the hypothalamic- pituitary-axis in regulating thyroid and growth hormones that have been shown to affect differentiation and proliferation of somatic and gonadal cells. However, under high ambient temperature and humidity the efficiency of feed utilization would be compromised and reproductive function deteriorates, as a consequence of impairment in appetite and subsequent oxidative stress due to hyperthermia. In addition consequent effects of thermal stress may also involved activation and or inhibition of the hypothalamus-pituitary liver axis. Apparently rabbits require a high protein diet in order to compensate for low feed intake under hot climatic conditions; and dietary selenium as a potent antioxidant. Therefore dietary protein and selenium supplementation at appropriate level of inclusion apparently have the potential to improve male rabbit general performance at reasonable cost.

Keywords: ambient temperature, male rabbit, protein, reproduction, selenium

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INTRODUCTION

Rabbit production has enormous potential in alleviating the problem of animal protein supply in developing countries as it is considered a cheap alternative animal protein source. The upsurge in demand for animal protein coupled with economic hardship has triggered much interest in fast growing animals that have a short generation interval.

Rabbit production in the tropics

Apparently rabbit has the potential of providing the cheapest and sustainable means of producing high quality protein for expanding populations, particularly in developing countries located in the tropics. Boland *et al.* (2013), have shown that rabbit is currently considered as a novel production animal, hence its potential and important contribution to future animal protein supply to human should not be overemphasized. Rabbits can turn 20% of the protein they eat into edible meat, and thus are comparable to broiler chickens (22 to 23%), pigs (16 to 18%) and beef (8 to 12%)(FAO, 2001). Furthermore, animal protein sources are of higher nutritional value than those from vegetable sources due to their amino acid composition. However, it has been shown that heat stress alongside poor forage quality have resulted in serious challenges to efficient reproductive and productive performance in sheep (Marai *et al.*, 2008), and in most livestock production (Oseni, 2012) in the tropics. Reproductive traits in rabbits were shown to be highly susceptible to detrimental effects of ambient temperature above 25^{o}C (Safaa *et al.*, 2009), which could alter male fertility with subsequent economic loss. A number of reports have implicated deterioration in semen quality as a consequent effect of distorted spermatogenesis in rabbits (Roca *et al*., 2005). Dietary protein and Se have been shown to modulate body composition and growth rate in animals (Bryden and Harper, 2008; Elmaz *et al.*, 2007; Zhang *et al.*, 2011). Reports on protein and Se supplementations in male rabbits are scarce, besides their inclusion in excess of requirement in several livestock species had been characterised by physiological alterations. As such, supply of adequate nutrition at appropriate level particularly during hot period is imperative considering nutrient requirements of rabbits.

Therefore, this study aims to highlight the effects of dietary protein and selenium supplementation on the reproductive and productive performance of male rabbits under tropical climatic conditions.

Significance of male breeder rabbits in a production system

Male breeder rabbits have enormous potential with regard to stock population and sustainable reproductive capacity in livestock production. For an animal to successfully reproduce puberty must be attained, leading to sexual maturity which eventually serves as a gateway to procreation of the animal's species (Osinowo, 2006). Spermatogenesis commences at puberty, approximately 15-18 weeks of age, with subsequent sexual maturity attained by 20-24 weeks of age, depending on breed, body size and nutritional status of the animal.

Male rabbits can breed throughout the year in tropical and subtropical environments, even though its reproductive capacity may decline during hot periods. This is unlike seasonal breeders in which reproductive capacity is affected by changes in day length (Marai *et al.*, 2007). Therefore, some male species of animals in the tropics, particularly non-indigenous breeds, can experience certain restrictions in terms of sexual activity and productivity because of seasonal variations, which in turn may negatively impact upon the production system. The importance of the male is well recognized, even at small scale subsistence production in the sub Saharan region of Africa, where exchange of male rabbits for breeding has been observed in order to exploit their genetic potential (Abu *et al.*, 2008).

The ejaculate volume of an adult buck ranges from 0.5 to 1.5ml, with a sperm concentration ranging between 100-300 x 10^{6}/ml. However, several authors have implicated a number of genetic, management and physiological factors affecting male fertility (Nwoko and Ibe, 2005; Garcia *et al.*, 2008). In addition, other studies revealed a reduction in male fertility in hot tropical and subtropical climates which subsequently led to impairment of production and reproduction (Marai *et al.,*, 2008; Elnagar, 2010; Okab, 2007). Research has indicated the importance of nutritional modifications of male rabbit diets in order to alleviate the negative effects of temperature, with respect to seminal characteristics (Habert *et al.*, 2005), sperm production rate and testicular sperm reserves (Bitto and Olokpo, 2005). The adoption of good husbandry practices that could lead to improvements in male reproductive potential is of paramount importance in order to ensure all services result in conception for sustainable production.

The production characteristics of rabbits

Rabbits are rapidly growing animals that have a short generation interval and are highly prolific and a cheap alternative source of animal protein (Table 1) (NRC, 1991). In addition rabbits can survive well on a diet containing poor quality forage with the addition of some concentrate feeds, mineral supplements and water (Oyeyemi and Okediran, 2007).

Furthermore, rabbit meat has a very low fat, cholesterol and sodium content, thereby making it a very good source of animal protein (NRC, 1991; Nodu, 2000). Due to these health benefits and the need for low capital investment coupled with quick turn over makes rabbit meat production an ideal means of alleviating national meat shortages and increase farm income in most developing countries, as well as peri - urban/suburban populations in some developed nations.

Lukefahr and Cheeke, (1990) reported daily body weight gains of 10-20g/d in rabbits from a tropical environment, whilst 35-40g/d is achievable in more temperate countries (Table 1). However it has been shown that prolonged exposure of rabbits to ambient temperatures above 30^{o}C reduces fertility and growth (NRC, 1991). However, Lukefahr and Cheeke (1990) have shown that specific genetic effects such as growth traits could strongly affects rabbits environmental adaptability. These may include body weights, ear length and fur density (hair coat) (Lukefahr and Ruiz-Feria, 2003).

Table 0: Production characteristics of typical New Zealand White and California rabbits

Parameters	Characteristics
Husbandry nutrient required per ration	16 g/100gCP, 18g/100gCF, 10.47J – 12.14J
Medium weight breed	3.6 - 5.4 kg
Sexual maturity and fecundity periods	4.0 – 5.0 months, till 4.0- 6.0years
Average gestation period(doe)	30 days
Number of kits born per litter	8.0 – 10.0 (intensive)
	5.0 – 8.0 (subsistence)
Number of kindling per year or litters/yr	8.0(intensive) 5.0 (subsistence)
Weaning age	3.0 – 4.0 weeks
Market weight attained at 2.3kglivewt	8.0 – 10.0 weeks to yield 2kg meat (intensive)
	16.0 weeks to yield 2kg meat (subsistence)
Mature weight category across breeds	1.0 – 6.0 kg (65-80g/kgbody weight)
Average daily feed intake (adult)	120.0 – 150.0g
Average daily gain (adult)	35.0 – 40.0g (temperate climate)
	20.0 – 25.0g (tropical climate)
Total number of kittens produced per year	20 – 25 kittens/ doe

Adapted from: Aduku and Olukosi, (1990); Cheeke,(1987); FAO,(1997); Lukefahr and Cheeke, (1990);Moreki,(2007); NRC,(1977); NRC,(1991).

Modification of animal production efficiency

The important avenue of improving animal production efficiency is optimising protein quality in order to achieve desired animal production at a minimum cost. Therefore alternative strategy need to be developed and more efficient production practices employed. The sustainable development of low- input rabbit production systems through identification of a more precise nutrient requirement and a basic reproductive management is imperative. Lebas and Gidenne (2000), has reported that balancing the nutritional need of the rabbit to get optimum performance is necessary, due to the fact that basic international information and or recommendation is scarce.

Protein supplementation in tropical Animals

In hot climates rabbits require a higher protein diet in order to compensate for low feed intake. Therefore, modification of dietary protein levels has been shown to compensate for seasonal changes in feed intake (Cervera and Carmona, 1998). Different protein levels are already offered to rabbits experiencing differences in environmental temperatures, with a higher optimum level of 180 g/kg CP in the tropics as compared to 160 g/kg CP in more temperate climates (Cheeke,1987)**.** However the increasing demand for animal protein coupled with rapid human population increases will create a significant problem in the adequate protein supply to both animals and humans in most tropical countries. According to FAO (2006a) reports, population increase is projected to be rapid in developing countries between 2000 and 2050, and most affected region would be Sub-Saharan Africa that are located in the tropical regions.

Protein supplementation in animal production

Protein is a critical nutrient that plays a vital role in livestock production and reproduction which includes body building (growth) and the repair of body tissues, synthesis of hormones, nucleoproteins, enzymes and antibodies (Aduku, 2004; Fraga, 1998; Cheeke, 1987). The protein used in diets of livestock originates from a variety of sources, such as cereal, legumes, forages, animal meals and various by-products (Boland *et al.*, 2013). Groundnut cake and Soybean meal are the conventional sources of protein in livestock production in Nigeria. However, the utilization of these protein sources would largely depend on their type and/ or animal species. For example it has been shown that soybean meal digestibility on dry matter basis could be about 620g/kg, as around 380g/kg of its total protein ingested may not be absorbed (Boland et al., 2013).

Basically, dietary protein that contains important amino acids is essential for vital body productive (Bergen and Merkel, 1991) and reproductive processes (Elmaz et al., 2007). Thus, optimal requirements for rabbits are for essential amino acids rather than crude protein itself (Fielding, 1992). Literally, amino acids are considered essential because their carbon skeletons could not be synthesised in animals (Fraga, 1998), thus are required in the diet or synthesised by gut microbes. Bergen and Merkel (1991) demonstrated that arginine and leucine stimulate the secretion of insulin and GH, both of which play a major role in protein accretion. Furthermore, the addition of lysine has been reported to ameliorate the detrimental effects of heat on poultry and swine (Cervera and Carmona, 1998).

Thus an effective method of improving protein quality in manufactured diets could be via dietary supplementation. However, excess protein intake has its own implications, particularly in rabbits which could result in accumulation of ammonia in the caecum (Cheeke, 1987). High protein diets, possibly in excess of requirements, have been shown to have a deleterious effect on semen characteristics in rams (Elmaz *et al.,* 2007), these authors attributed this to probably accumulation of excess fat in the testes. Conversely, other reports showed that, intake of low dietary protein may result in depressed growth and reproductive performance in rabbits (Lebas *et al.,* 1998) particularly in stressed conditions, due to possible imbalance nutrients for normal body processes and functions. In addition, maintaining the protein energy ratio in hot climatic conditions is of paramount importance, hence standardizing the optimal protein requirement for better growth and reproduction is essential. Therefore alleviating the endogenous losses of protein by enhancing the digestibility of the current and alternative protein sources would contribute to an improvement in dietary efficiency or utilization.

Effect of protein on male reproduction

Dietary protein has shown great potentials to enhance the reproductive traits in male rabbits. The report by Elmaz *et al*., (2007), stated that dietary protein could play a vital role in modulating the effects of IGF-I on testicular tissue growth and development. Similarly Ladokun *et al*. (2006) also indicated that male rabbits require dietary protein level of 20-24% CP for optimum reproductive functions in humid tropics, stressing that when rabbits were fed diets containing 14%CP for certain period of time, the testis were shrunken with subsequent narrower seminiferous tubules. In addition it has been shown that dietary inclusion of more than 15% level of crude protein was suggested to ensure optimum sperm production in rabbits (Nizza *et al*., 2000). Thus this improvement on testis length could probably be as a response of amino acid uptake for subsequent tissue development, hence the gonadal sperm may be improved, since relatively high level of dietary protein diet appears to be effective for proper function of the male reproductive system. Since testes size has been known to be influenced by body weight and closely related to body growth. Dietary supplementation is implicated in enhancing hormonal secretions, enzymatic actions and antioxidant status, with subsequent improvement on reproductive tracts of an animal (WHO,2007; Hafez and Hafez, 2000; Castellini, 2008; Sahin et al., 2013).

Selenium supplementation to tropical animals

Selenium (Se) is a micro-nutrient that is required for a number of biochemical functions in both humans and animals (Mahima *et al.,* 2012); these include antioxidant, immune function, reproduction and thyroid hormone metabolism (BNF, 2001, Mclntosh, 2008**).** Thus, Se is one of the essential trace mineral (NRC, 1994), serving as an essential co-factor in the antioxidant enzyme glutathione peroxidase (GSH-Px), as well as catalase (CAT) and superoxide dismutase (SOD) in the body, to counteract the damaging effects of reactive oxygen species (ROS) and numerous peroxides in rabbits (Zhang *et al.,* 2011), that are known to manifest and increase in their destructive activity in tissues of rabbits during thermal stress (Liu *et al*.,2011). Therefore animals require Se in their diets, but at an appropriate level as the element is toxic at high levels.

Selenium supplementation in animal production

Selenium could not only have the potential to prevent oxidative damage during heat stress, but could also influence maintenance of cell membrane integrity via phospholipid hydroperoxide glutathione peroxidase (Mahima et al., 2012). Furthermore, it was reported to be implicated in body metabolism and growth (Liu et al., 2011), since Se was shown to form an integral part of the deiodinases (Zhang *et al*.,2011), but, this particular changes only occurs, when the levels of dietary Se are extremely low or deficient within the body system, such that other selenoproteins might have been metabolically inadequate. Selenium has been implicated in supporting cellular processes of the body (Burk, *et al.,* 2003), through homeostasis. Body weight gain, feed conversion efficiency and antioxidant capacity of growing rabbits was improved when offered supplementary dietary Se at a rate of 0.24mgSe/kgDM (Zhang *et al*., 2011). Conversely, Dokoupilova *et al.* (2007) reported that Se supplementation in rabbits did not effectively influence the rate of growth, feed efficiency or carcass yield.

The discrepancies on these reports concerning the bioavailability and effects of dietary Se supplements may depend on age, animal species, level of inclusion, chemical form/molecular form, quality of diets, and availability of other nutrients in the diets, as well as environmental influence (NRC, 1983). Considering the fact that absorption of ingested Se was shown to be as much as 80% but efficiency of its utilization could be altered by forming complexes with other metals and thus decreases its bioavailability (Mahima et al., 2012). These authors also showed that decrease bioavailability of most metallic selenides resulted in less toxicity, but the selenates and selenites appears to be very toxic because of their antioxidant mode of action and high absorptive rate. In contrast, Dunshea and Uglietta, (2008), have shown that organic forms of Se (selenized yeast and selenomethionine) are better utilized due to higher bioavailability with minimal toxicity potential, whereas inorganic forms (selenates, selenides and selenites) may act as pro-oxidant and be toxic at increased dietary concentration. Nevertheless, research studies have shown that both organic and inorganic forms of Se could be toxic in large doses, and that organic forms are considerably less toxic than inorganic forms of Se (NRC, 1983; Fairweather-Tait et al., 2010; Saxena and Jaiswal, 2007). However a more recent reports in rabbits, indicated that Se could render its toxicity partly by forming selenite ion free radical which in excess can combine with glutathione to form superoxide anions and subsequently other reactive oxygen species are produced resulting in peroxidative damage (Zhang *et al*., 2011). Similarly, it has been shown that selenite is regarded as the most toxic form of Se because it facilitates oxidation reactions (sulfhydryl metabolites), as it could easily bind to plasma protein and enter into circulation, and subsequently find its way into various cells and tissues (Fairweather-Tait *et al*., 2010), but less well retained as compared to selenomethionine.

Studies in lamb by Juniper *et al* (2009), indicated that the presence of selenomethionine is indicative of Se uptake in animal tissues, while selenocysteine within the tissues indicates glutathione activity. It has been shown that Selenomethionine follows the metabolic pathways of intact methionine, therefore during low level of methionine, selenomethionine will be directly but non-specifically incorporated into general body proteins in place of methionine (NRC, 1983; Schrauzer, 2000). According to Calamari *et al*. (2008) on studies in horses, observed that Se is mainly absorbed from the duodenum, and better absorbed from high protein diet. In addition Selenomethionine has been reported to be much more rapidly absorbed than selenocysteine, however both were well retained than inorganic forms.

Response of reproductive traits in male to selenium supplementation

Marai *et al* (2009), conducted a study in which rams were offered diets supplemented with 0.1 mg Se/kg DM as sodium selenite during the summer period and observed a positive effect on reproductive and physiological traits, such as increased sperm concentration, sperm motility and decreased sperm abnormalities and dead spermatozoa. Thus, dietary Se seems to have enormous potential with a positive impact on the thermoregulation and reproduction in animal production (El-Raffa, 2004; Marai *et al.*, 2009). Beneficial effects of Se has been predominantly observed in the testes, with higher activity/deposition in the nucleus and midpiece of the sperm cells and subsequent positive impact on expression of genes related to the transcription of selenoproteins (Kehr *et al*., 2009). In contrast, studies in rams by Marai *et al*., (2009), have shown that Se could either directly affects the interstitial cells of the testes or serve as a structural component of the sperm cells.

Phsopholipid GSHPx formerly known as sperm capsule selenoprotein have been shown to improve structure of the sperm cells in rats, whereas Selenoprotein P and thioredoxin-glutathione reductase are important in spermatogenesis (Kehr *et al*., 2009). In addition, other reports in rats indicated that Selenoprotein W was discovered in interstitial cells of the testes, and therefore Se could have a positive effect in androgen (Testosterone) production, hence may influence semen quality (Yeh *et al*., 1997). However it was indicated that, normal function of selenoenzymes to the testes could be adversely affected by stress factors, especially when oxidative stress overwhelmed antioxidant status, and this could subsequently inactivate or rather suppress normal function of Selenoprotein P (Kehr *et al.,*2009), which has been shown to serve as the main transport mechanism for Se in the body (Saxena and Jaiswal, 2007). In addition, Yeh *et al*. (1997) indicated that testes of rats have shown elevated activity of the selenoenzymes, phospholipid glutathione peroxidase (GSHPx4) and selenoprotein W when fed 1.0mg Se/kg diet.

It was found that testicular mitochondria are sensitive to oxidative damage in sheep (Yan *et al*., 2010 and rats (Pino *et al.*, 2013), however it was shown that seminal plasma has some degree of protection against oxidative damage, as it contains antioxidant enzymes such as catalase, superoxide dismutase and glutathione-s-transferase (Maia *et al.*, 2010). The activity of these enzymes has been shown to improve in the presence of Se. Therefore, the depletion of endogenous Se pools, particularly in hot summer periods, could result in spermatozoa and testicular tissues (seminiferous tubules, leydig and sertoli cells) to be more susceptible to damage by reactive oxygen species (ROS), due to the fact that lipid is a basic component of testicular and spermatozoa membranes and hence more susceptible to damage by free radicals (Gundogan *et al.*, 2010). Since, peroxidative damage to spermatozoa has been shown to be one of the major causes of male subfertility (BNF, 2001). It is thus considered expedient to exploit dietary Se supplementation as a form of nutritional strategy to counteract the adverse effects of heat stress in rabbit productive and reproductive performance in order to enhance successful production all year round.

Therefore, investigating a range of biochemical and haematological parameters as well as other biomarkers of hyperthermia such as rectal temperatures and respiratory rate, may be indicative of physiological stress and tissue damage that may provide a scientific means of determining indicators of metabolic adjustment and behavioural responses which might occur as a consequence of heat stress. In addition, evaluating sperm and semen characteristics and testicular measurements provides a standard procedure for determining the temperature dependent effects on male reproductive organs. Furthermore identifying variations that might have evolved between treatment groups and that of temporal effect, could be used to select and maintain adaptive traits.

Thermal stress as a constraint to rabbit production

Research has shown that environmental temperatures above 28^{o}C could cause oxidative stress and impair antioxidant status *in-vivo* in rabbits (Okab *et al.*, 2008). Considering the fact that rabbits have low thermal tolerance, as their thermo - neutral zone (TNZ) is around 15-21^{o}C (McCroskey, 2001; Marai *et al*., 2002). Therefore, exposure of rabbits to environmental temperatures above 30 - 35^{o}C resulted in thermal stress which subsequently adversely affected their performance (NRC, 1991; Liu *et al*., 2011).

Heat stress on male reproductive performance

Testicular tissues and membranes seems to be highly sensitive to free radical actions that could cause lipid peroxidation (Gundogan *et al*., 2010), as a result of heat stress. Giving the fact that, active sperm cells under normal circumstance undergo high glycolytic processes to generate energy, with subsequent production of reactive oxygen species (ROS), which may be useful in maintaining proper testicular homeostasis during spermatogenesis (Rodriguez *et al*., 2008). Therefore ROS have been characterised as molecules in seminal plasma that could be used as biomarkers of spermatozoa fertility, thus their production in the body including the testes, is a normal physiological process (Yousef *et al*., 2003). However, when the ambient temperature goes beyond the thermo- neutral zone, the ROS may be in excess due to oxidative stress, which could have detrimental effects on reproductive capacity of the animals, with subsequent decrease in testicular size and reduced semen quality. Hence, reproductive traits appear to be much more vulnerable to high environmental temperature.

The effects of high environmental temperatures on semen characteristics and growth traits of farm animals had been widely reported (El-Raffa, 2004). Thus, high ambient temperatures of tropical regions had been implicated in poor reproductive performance in most livestock species. Studies in rabbits have shown increases and or dysregulation in oxidative enzymes (glutamic oxaloacetate transaminase & glutamic pyruvate transaminase, CAT, SOD and GSH-Px) and other catabolic agents (cortisols & catecholamines) which subsequently altered biological efficiency (digestive and reproductive capacity) and productivity of the animal, resulting in negative consequences (Marai *et al.,* 2008; Okab *et al* ., 2008). Higher sperm abnormalities affecting sperm tail has been observed in ejaculates of rabbits during the summer (30^{o} C) compared to other seasons (Finzi *et al*., 1995; Bodnar *et al.*, 2000). Conversely Okab (2007) did not observe any effect of season on sperm abnormality in rabbits, but on some other parameters such as sperm concentration and motility. Therefore morphological abnormalities could serve as biomarkers of sperm quality as well as indicators of heat stress. Literally, oxidative stress has been shown to cause various types of damage on sperm cells, such as irreversible loss of motility, leakage of intracellular enzymes and damage to chromatin (Gundogan *et al*., 2010). Thermal stress has been shown to activate and generate excess ROS, which are normally produced as by product of body metabolic processes in rats spermatogenic cells (Pino *et al*., 2013). ROS is a collective term that includes not only free radicals of oxygen but also some non - radical derivatives of oxygen, such as hydrogen peroxide (H_2O_2) and singlet oxygen.

Heat stress and physiological adaptation

Heat stress results in dairy cattle a reduction of plasma growth hormone production and triiodothyronine (T_3) concentrations (McGuire *et al*., 1991), a consequence of reduced feed intake. This in turn causes concentrations of Insulin Like Growth Factor-I (IGF-I) to rise (Sarko *et al.,* 1994). The detrimental effect of heat stress on rabbits may be a consequence of decreased feed consumption, dehydration and tissue catabolism (Marai *et al*., 2008) which can lead to impaired immunity and reduced body weight. However, it has been suggested that feed intake, or the action of eating, increases animal heat production as a result of metabolic processes within the body (Marai *et al*., 2009; Hansen, 2009). Therefore reduction in feed intake and the subsequent decline in digestive function may be a natural way of adjusting or controlling excess heat load in animals within a heat stressed environment (Figure 1). Thus, the most appropriate and cost effective method of intervention is the development of nutritional

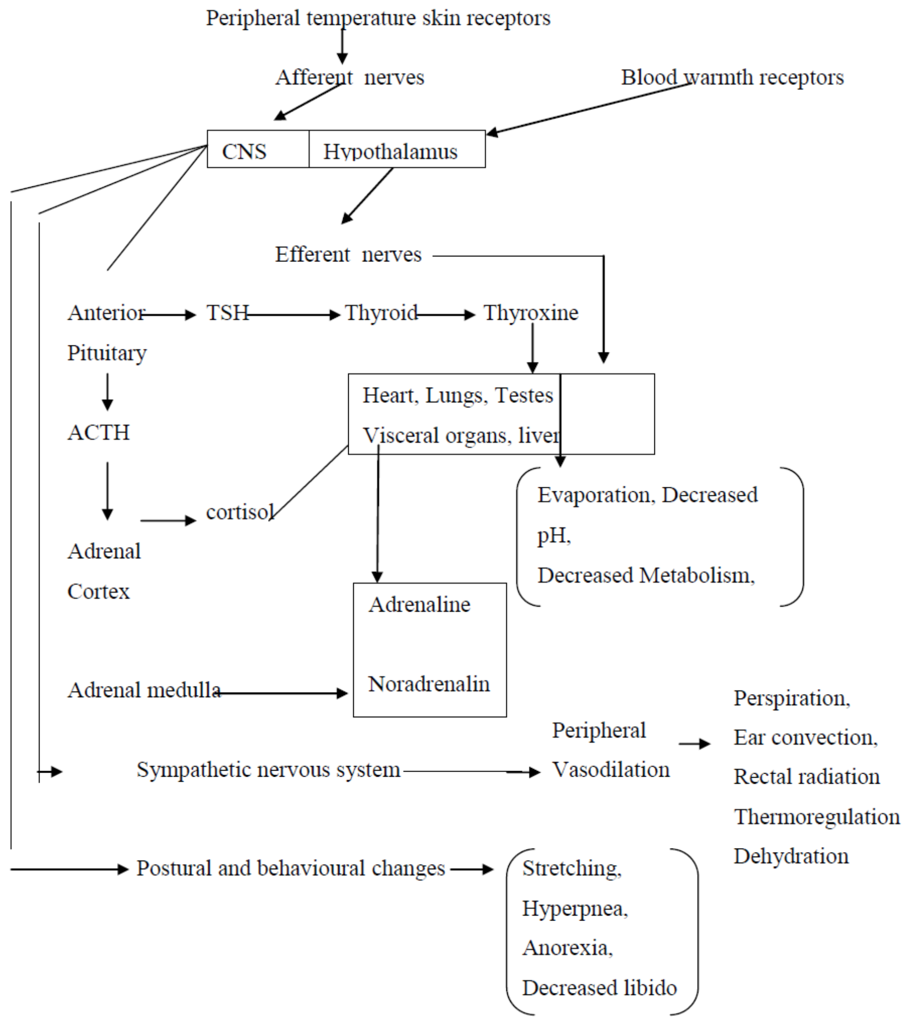

Figure 1: The pattern of Physiological responses to heat exposure
Adapted: Yousef (1985);
CNS = central nervous system; TSH= thyroid stimulating hormone; ACTH = adrencorticotropic hormone.

strategies (McCroskey, 2001), that may effectively compensate for decreased feed intake and subsequent utilization.

As such high ambient temperatures may cause economic losses in livestock production, particularly in the rabbit industry due to the animals limited ability to dissipate body heat load, resulting in deleterious effects on growth performance (Liu *et al*., 2011), as well as reproductive performance (Marai *et al*., 2002). Consequently this thermal stress results in activation of both the hypothalamic-pituitary adrenal axis (HPA) and the sympatho-adrenal medullary system (SA) (Koch, 2004). Literally under heat stress, it has been shown that the HPA axis is activated and glucocorticoids are secreted by the adrenals resulting in anti-anabolic effects (Gesquiere *et al.*, 2011).

Schematic pathways of thermal stress

Heat stress as a consequence of hyperthermia was shown to aggravate cellular destruction in rams, resulting in rapid oxidation of lipids, proteins and nucleic acids (Marai *et al*., 2008), which could reduce protein synthesis with subsequent reductions in growth rates and levels of reproduction. In addition, during heat stress, it was reported that, rescue proteins such as Hsps tends to be activated and increased in the circulation in order to protect body cells and tissues from oxidative damage (Kalmar and Greensmith, 2009)(Figure 2). In line with

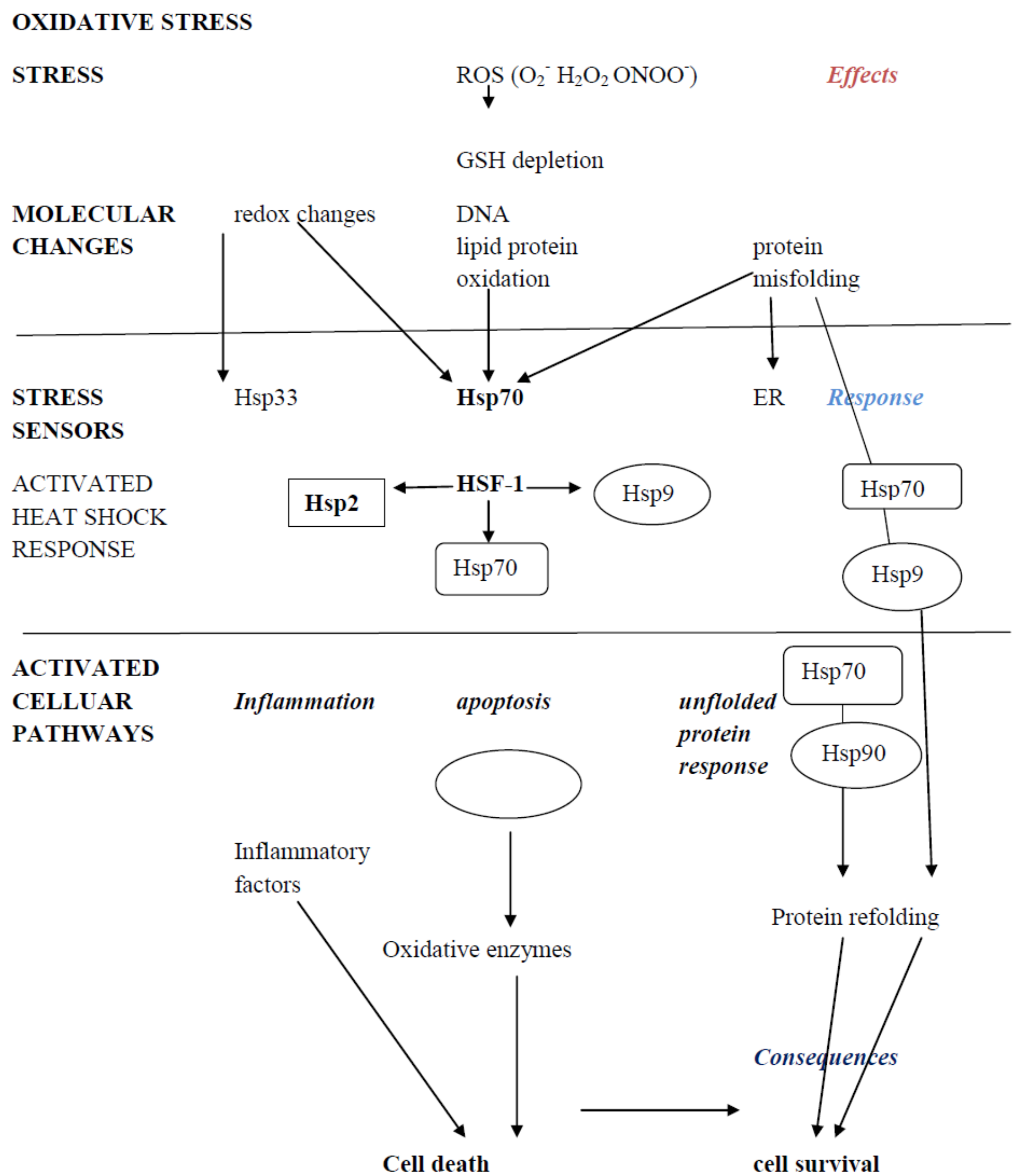

Figure 2: Molecular and Cellular responses to heat stress exposure
Adapted : Kalmar and Greensmith (2009)

this, Marai *et al*. (1991) also reported that performance of New Zealand White rabbits kept at temperatures of 32.2-35°C in the tropics was not compromised, postulating that animals kept routinely under high ambient temperatures develop metabolic mechanisms to help adapt to heat stress. This therefore indicates that, animals at some point may develop an adaptation mechanism against heat stress, thus signifying a process of acclimation. The progressive decrease of RH below 75%, improves rabbits ability to withstand high ambient temperatures (Marai *et al.,* 2002). This may probably be due to an increased capacity to lose body heat through vaporisation and/or radiation, as the air is less humid.

Temperature Humidity index and heat stress

A mathematical model to determine the precise effect of heat stress on animal performance, have led to the development and application of the Temperature-Humidity Index (THI) (Marai *et al.*, 2002). THI gives an indication of the level of severity of heat stress by combining two factors; temperature (^{o}C) and relative humidity (%), which are important environmental factors affecting the animals ability to regulate body temperature. Therefore, THI could be used to determine the combined effect of heat and humidity on testicular, seminal and biochemical characteristics of production animals (Roca *et al.*, 2005; Marai *et al.*, 2008).

Other Management constraints

The disparity in production levels between developed countries and developing nations on technical aspects of rabbit production, has been attributed to low technical skills as constraints to most developing countries (Lukefahr and Cheeke, 1990). Even though rabbit meat can be produced relatively cheap at subsistent level, in most tropical and subtropical developing countries, certain measures or strategies need to be developed and adopted in order to achieve commercial production successfully. Therefore it has been shown that, successful development of rabbit production relies on efficient and effective management and organized market strategies (CSIRO, 2002). This author further pointed out that rabbit skin and its by-products are wasted most probably due to lack of processing skills and organized marketing system. Basically organized and regular updated data on rabbit production in developing countries is lacking because of uncoordinated production schemes (Onifade et al., 1999). Perhaps, proper management strategies that are cost effective, whether economic or nutritional, would ultimately shift the production level from subsistence to commercial as it is in most developed countries.

CONCLUSION AND RECOMMENDATION

High ambient temperatures have been found to impair fertility in male rabbits, most likely as a consequence of heat stress, and a number of reports indicated alterations in the normal physiological processes in heat stress situations. The fertility of males and females in a particular herd/flock, as well as level of nutrition to a large extent, determines the rate of production in any livestock industry. Therefore, understanding the inherent qualities of rabbits with respect to changes in ambient temperatures under tropical climatic conditions could result in effective exploitation of their capacity towards a successful production system. Nutritional strategies that include the use of macro and micronutrients have been shown in other classes of livestock to reduce the deleterious effects of heat stress. Similar potent and cost effective strategies rather than physical or hormonal could be employed to improve the productive and reproductive performance of male rabbits, which appears to be promising.

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