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HAEMOGLOBIN POLYMORPHISM IN SELECTED FARM ANIMALS-A REVIEW

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Review paper

Abstract: Biochemical diversity or polymorphism is the occurrence of varieties attributed to biochemical differences which are under genetic control. It has created a leeway for the genetic improvement of farm animals. This is because it can be used as a useful tool for the characterization of livestock breeds and population. This way, the degree of similarity or differences within and between breeds can be ascertained and this differences or similarity are important raw materials for genetic improvement of animals. Data obtained on gene frequencies and genotypes through polymorphism study makes it not only possible to compare the gene stocks of animals, the possible effects of the genes on reproductive and performance traits, but also study genetic variability under different environmental conditions of selection. This study was carried out to review haemoglobin (Hb) polymorphism in selected farm animals with the view of finding out the type of polymorphism observed by starch gel electrophoresis due to variation in the amino acid sequence in the polypeptide chains of Hb. The review showed clearly that there is a gene-controlled diversity in the different farm animals considered. This could serve as a reference point for future studies earmarked for the improvement of the animals possibly via marker-assisted selection.
Key words: Biochemical polymorphism, haemoglobin, livestock, gene and genotype frequencies.

Introduction

Genetic differences exist in all farm animals which lead to variability in the reproductive and performance abilities of animals both within, and between breeds. Differentiating this variability could be a basis for selection and subsequent genetic improvement of farm animals. Biochemical polymorphism study is one way of delineating genetic variation in animals. *Osterhoff (1964)* defined polymorphism as the occurrence together of two or more varieties in the same population at the same time in such proportions that the rarest of them cannot be maintained by mutation alone. Biochemical polymorphism on the other hand as defined by the same author, is the occurrence of varieties attributed to biochemical differences which are under genetic control. A population is said to show polymorphism when two or more distinctly inherited varieties coexist in the same individual *(Das and Deb, 2008).* This type of polymorphism is increasingly being used in the study of genetic variation within and between populations and to estimate genetic divergence *(Lee et al., 1995).* This is because the biochemical elements (blood proteins and enzymes) can be used widely as biomarkers of corresponding structural genes. These biomarkers are not affected or do not depend on environmental factors and this makes them suitable for genetic studies.

Recently, a large number of biochemical polymorphic characters of farm animals have been scrutinized. Characters such as transferrin, Hb, albumin, alkaline phosphatase etc have been reported to exhibit polymorphism *(Das and Deb, 1995).* This study has become imperative because of their importance in the improvement of farm animals, and the fact that some polymorphic alleles may be connected or linked with traits of economic importance due to pleiotropic effect, or general heterozygosity. For instance, marginally but not significant better body weight had been reported in Hb BB type animals *(Arora et al., 1971).* In sheep however, Hb AB and Hb BB had been observed to have an effect on sheep performance *(Dally et al., 1980; Barowicz and Pacek, 1984; Arora, 1984; Dratch et al., 1986).* Blood protein polymorphisms have been used to study evolutionary relationships in many animals *(Kalab et al., 1990; Emerson and Tate, 1993; Buchanan et al., 1994; Guney et al., 2003; Malan et al., 2003; Yang and Jiang, 2005; Al-Samarrae et al., 2010, Akinyemi and Salako, 2010; Yakubu and Aya, 2012; Agaviezor et al., 2013; Yakubu et al., 2014).* Although there are more advanced technologies for genetic studies of polymorphism in farm animals, the economic situations and inadequacy of infrastructural facilities in developing countries means that the importance of such studies using starch gel electrophoresis cannot be discountenanced. The objective of this write up therefore, is to undertake a review of relevant literature on Hb polymorphism in selected farm animals (cattle, sheep, goat and chicken).

Haemoglobin

Haemoglobin is a blood protein which contain four globin chains (two each of alpha and beta), and a prosthetic group called haem bound to each other *(de Souza and Bonilla-Rodriguez, 2007).* Human haemoglobin was the first protein analysed *(Osterhoff, 1964)* and the most studied blood protein *(Yakubu and Aya, 2012).* It is the respiratory carrier of oxygen and carbon dioxide to and from body tissues and cells. The haem portion of Hb is alike in all forms of Hb with genetic variation restricted to the structure of the globin portion only *(Chineke et al., 2007).*

Since there are structural differences at the globin portion of Hb, variants of it are likely to result and these variants may confer or limit animal's abilities/productivities, or confer certain advantages. *Ndamukong (1995)* reported on selective advantages in different geographical regions due to different Hb types. Such selective advantages include but not limited to resistance to helminthic infestation *(FAO, 1988; Ndamukong, 1995)*, effect on meat quality *(Bezova et al., 2007)*, productive traits *(Dally et al., 1980; Barowicz and Pacek, 1984; Arora, 1984; Dratch et al., 1986; Henkes et al., 2000; Boonprong et al., 2007)* and, hair and hair length *(Akinyemi and Salako, 2010). Di Stasio (1997)* opined that this could be due to better functional properties of the Hb molecule concern as a result of greater affinity for oxygen and higher Hb concentration and packed cell volume. *Thompson and Thompson (1980)* and *Peters et al. (2004)* reporting on the importance of Hb stated that, it has revealed more about the molecular basis of human, animal and medical genetics, vital for the part it plays in demonstrating the relationship between genetic information and protein structure, illustrated the mechanisms of new gene formation other than by point mutation as well as its importance in shedding more light on the causes of a variety of genetic disorders of the blood. The importance of Hb can therefore not be over-emphasized.

Haemoglobin polymorphism

Cattle. Haemoglobin polymorphism was first actually reported in the Algerian hill cattle *(Cabannes and Serain, 1957; Pal and Mummed, 2014).* Haemoglobin polymorphism in cattle seems to be breed influenced as some breeds have been shown to show a clear polymorphism with two alleles (AA, BB) and their possible phenotypes (AA, AB and BB), while others present only one allele type-AA *(Osterhoff, 1964).* Most studies have however reported on the occurrence of the two co-dominant alleles Hb A and Hb B *(Naik et al., 1968; Henkes et al., 2000; Pal and Mummed, 2014).* Apart from the co-dominant Hb A and Hb B types, other variants have also been reported such as Hb X, with a motility that is intermediate between those of Hb A and Hb B in Indian cattle *(Naik et al., 1965).* Another variant Hb C whose electrophoretic motility is similar to that of Hb X was also reported in the American Brahmin cattle by *Crockett et al. (1963)*. Other variants reported include Hb Khillari with motility slower than that of Hb A in Indian cattle *(Naik and Sangvi, 1964)*, and still another Hb variant which was slower than Hb A in Muturu cattle of West Africa *(Efremov and Braend, 1965). Majid et al. (1994)* observed a single type of Hb pattern; Hb AB in Tamaraw (*Bubalus mindorensis*) cattle in the Philippines. *Schwellnus and Guerin (1977)* also observed the presence of Hb C variant in Brahman and seven indigenous cattle breeds of Southern Africa. *Ahmed et al. (2010)* however, reported four Hb variants in their study with cows and buffaloes with allelic frequencies of 0.51, 0.33, 0.014 and 0.01 for Hb A, Hb B, Hb C and Hb D, respectively. *Pal and Mummed (2014)* reported an allele frequency of 0.709 and 0.291 for genotypes Hb AA and Hb AB, and gene frequencies of 0.502, 0.411 and 0.084 respectively for Hb AA, Hb AB and Hb BB in Ogaden cattle in Ethiopia which is consistent with gene frequencies reported for Somalian Boran and Dawara cattles *(Di Stasio et al., 1980)* and Bunaji cattle of Nigeria *(Essien et al., 2011)*. High prevalence of Hb AA has also been observed in *Bos taurus* catlle *(Braend, 1972; Tejedor et al., 1986).* It has been suggested that Hb type may have been influenced by environmental factors *(Bangham and Blumberg, 1958; Balakrishnan and Nair, 1966; Sen et al., 1966; Ajuwape and Antia, 2000; Tibbo et al., 2005; Essien et al., 2011)*. The mechanism for such polymorphism has however not been made clear *(Al-Samarrae et al., 2010)* and needs to be further studied. Equally, no direct evidence exists of differences among the three Hb phenotypes (AA, AB and BB) for fitness has been found in cattle *(De Vito et al., 2002). Bangham (1963)* reported that Hb type did not significantly affect milk yield and butterfat percentage in dairy cattle.

Sheep. The existence of three major Hb types (AA, AB, and BB) caused by Hb A and Hb B genes and the existence of some rare Hb types have been reported in the sheep *(Evan et al., 1958a; Missohou et al., 1999; Miresa, 2003; Mohri et al., 2005; Al-Samarrae, 2006; McManus et al., 2009; Tsunoda et al., 2010; Al-Samarrae et al., 2010)*. In contrast to other animals, Hb A is the fastest moving Hb in the sheep based on electrophoretic motility *(Osterhoff, 1964)*. Different frequencies have been reported for the different Hb variants in the sheep. *Meyer (1963)* for instance, demonstrated the frequency of Hb A gene varying from 0.00 in the English Dartmoor breed, to 0.97 in the German Heid-Schnukle sheep. *Rao and Panandam (1998)* observed an allelic frequency of 0.16 (Hb A), 0.30 (Hb B), and 0.54 (Hb AB) with a gene frequency 0f 0.43 (Hb A) and 0.57 (Hb B) in Santa Ines hair type sheep population. *Al-Samarrae et al. (2010)* observed high frequencies; 0.98, 0.99 and 0.97 for Hb B in local Awassi, Arrabi and Karradi sheep breeds of Iraq while *Akinyemi and Salako (2010)* reported high frequency for Hb A in West African Dwarf sheep of Nigeria. Like in cattle, attempts have been made to link sheep Hb type with geographical location. *Huisman et al. (1958)* and *Evans et al. (1958a, b)* reported that sheep reared in higher altitude have a higher frequency of Hb A, and equally show a higher oxygen affinity. *Evans et al. (1958a)* observed that mountain and hill sheep breeds particularly of the Northern parts of Britain tend to have higher Hb A while those of the lowland tend to have Hb AB and Hb B, respectively. *Pieragostini et al. (2006)* observed that Hb A is found more frequently in sheep living above 40^{o} C latitude, while *Sun et al. (2007)* opined that sheep with Hb B were better able to withstand the stress associated with acute hypoxia compared to those with Hb A. *Akinyemi and Salako (2010)* reported a higher frequency of Hb A in West African Dwarf sheep of Nigeria as one moves towards the forest belt of the country. Similar trend was observed in the Yankasa sheep by *Tella et al. (2000)* as one move into the forest belt of Nigeria. In their study of Balami, Uda and Yankasa sheep breeds in the Northern part of Nigeria however, *Akinyemi and Salako (2012)* were able to show that Hb B was more predominant with allele frequencies of 0.75, 0.90 and 0.81 recorded for the Balami, Uda and Yankasa sheep, respectively. The predominance of Hb B over Hb A in sheep has also been reported by other authors *(Clarke et al., 1989; Zanoti Cassati et al., 1990; Bunge et al., 1990; Boujenane et al., 2008; Shahrbabake et al., 2010; Mwacharo et al., 2002)*. The difference in Hb allele of the sheep has been adduced to be due to selective advantages in the different geographical regions in which the animal finds itself. The selective advantage appears to be of adaptive significance in the regions in which the sheep finds itself, and possibly have an effect on its performance. For instance, *Tsunoda et al. (2006)* however reported that Hb A has a relatively high affinity for oxygen and is therefore very important for survival of the sheep in mountainous areas at latitude above 3000 m, while *Nihat et al. (2003)* in their study using Merino sheep crosses, showed that ewes with Hb types AB gave better lamb birth weight.

Goat. According to *Schmid (1962)*, there are two different Hb types in goat (Hb A and Hb B). Other authors who also reported on only two Hb types in the goat include: *Khanilkar et al. (1963), Garzon et al. (1976), Turker et al. (1983), Barbancho et al. (1984), Bhat (1986, 1987) and Tunon et al. (1987). Elmaci (2001)* also observed two Hb phenotypes controlled by the two co-dominant autosomal alleles Hb^A and Hb^B in hair goat breeds raised in Turkey with frequency of Hb^A being considerably higher than Hb^B allele. *Agaviezor et al. (2013)* however, reported the incidence of three Hb types (Hb AA, Hb AB and Hb BB) in the Red Sokoto goat, Hb AA and Hb AB in Sahelian goat, and only Hb AA in West African Dwarf goats sampled in the Niger Delta area of Nigeria. The gene frequencies for the alleles were: 0.80 and 0.20 (Red Sokoto goat), 0.77 and 0.23 (Sahelian goat), and 1.00 and 0.00 (West African Dwarf goat), respectively. In their own study of the West African Dwarf goat in the North Central region of Nigeria, *Yakubu et al. (2014)*, detected three co-dominant alleles, causing the presence of three genotypes (AA, AB and AC), with frequencies of 0.69, 0.30 and 0.01, respectively. They observed corresponding genotype frequencies of 0.37, 0.61 and 0.02, respectively. *Nafti et al. (2013)* reported frequencies of 0.779 and 0.757 (Hb AA), 0.206 and 0.226 (Hb AB), and 0.013 and 0.017 (Hb BB) for Arbi and Serti goats of Tunisia. In a pooled population of Indian Malabari goats, *Bindu and Raghavan (2010)* reported on the predominance of Hb A allele (0.927) over that of Hb B allele (0.012). *Johnson et al. (2002)* also discovered that Hb A was the only allele found in adult Batinah and Jebel Akhdar goats while studying three breeds of Omani goats. They equally observed that 34% of Dhofari goats were homozygous for Hb AB while 66% were heterozygous for Hb A and Hb B, respectively. The works of *Agaviezor et al. (2013) and Yakubu et al. (2014)* clearly reflected the predominance of Hb A over Hb B in West African Dwarf Nigerian goat breeds. This could be an adaptive feature for survivability of the West African Dwarf goat.

Poultry. Haemoglobins are heterogeneous in the fowl *(Osterhoff, 1964). Rodnan and Ebaugh (1957)* were of the opinion that the synthesis of fowl Hb is controlled by at least three genes. *Dimri (1978)* reported that three types of Hb have been observed in poultry which are controlled by two autosomal alleles A1 and A2, respectively. *Mazumder and Mazumder (1989)* observed the frequency of normal Hb gene in White leghorn to be 0.96, 1.00 in broilers, 1.00 in local fowl, 1.00 in the guinea fowl, and 0.85 in quail with corresponding figures for the normal mutant alleles being 0.04, 0.00, 0.00, 0.00 and 0.15, respectively. *Al-Samarrae et al. (2010)* from their work with White leghorn and native Iraqi chickens, observed both A and B Hb alleles at a gene frequency of 0.65 and 0.35 (Leghorn) and, 0.54 and 0.46 for the native Iraqi chickens, respectively. *Yakubu and Aya (2012)* analysed three indigenous Nigerian chickens (normal feathered, naked neck and Fulani ecotype), respectively and observed the frequencies of the A and B genes to be 0.68 and 0.32 (normal feathered), 0.71 and 0.29 (naked neck), and 0.75 and 0.25 (Fulani ecotype), respectively. The corresponding genotype frequencies for AA, AB and BB alleles were 0.54 and 0.28 (normal feathered), 0.58, 0.27 and 0.15 (naked neck), and 0.62, 0.26 and 0.12 for the Fulani ecotype chicken, respectively. They equally reported that, while the gene and genotype frequencies of naked neck and Fulani ecotype chickens were in Hardy-Weinberg equilibrium, those of the normal feathered birds deviated from the theoretical proportions. The three Hb types reported by *Yakubu and Aya (2012)* are consistent with the earlier findings of *Ugur et al. (2006)* in Chuckars and Pheasant, and *Salako and Ige (2006)* in indigenous chickens of South-West Nigeria. *Okamoto et al. (2003)* however reported that in general, Asian native fowls were being fixed at the Hb B locus with Hb A detected at extremely low frequencies in some chickens. Haemoglobin polymorphisms have been linked to some performance or survivorship traits in the chicken. *Washburn et al. (1971)* inferred that chickens of the homozygous mutant Hb genotypes were approximately 20% less susceptible to Marek's disease. *Dimri (1978)* reported that Hb polymorphism affects growth rate and hatchability, with the highest hatchability recorded for AA (62.20%) followed by AB (48.20%) and BB (31.50%), respectively. *Al-Murrani et al. (1996)* however did not observed any significant relationship between Hb type and some measures of resistance to coccidiosis in both native Iraqi and White leghorn chickens.

Conclusion

It is clear that there is gene-controlled Hb polymorphism in the animals treated and this could be useful in marker-assisted selection of animals for subsequent genetic improvement programmes. The possibility of tying the different genotypes to performance indices makes it all the more useful as animals could be selected based on their selective advantages for geographical region, resistance to pests and disease infestation and other economic factors of interest to farmers. Although simple starch gel electrophoresis could bring out the polymorphic differences existing in the Hb of farm animals, there is the need for more sophisticated screening of blood proteins using microsatellite markers and single nucleotide polymorphisms. This way more informed decisions could be made.

Polimorfizam hemoglobina u izabranim vrstama domaćih životinja

S.S.A. Egena, R.O. Alao

Rezime

Biohemijska različitost i polimorfizam je pojava varijeteta koja se pripisuje biohemijskim razlikama koje su pod genetskom kontrolom. Polimorfizam je stvorio slobodu za genetsko unapređenje domaćih životinja, zbog toga što se može koristiti kao alat za karakterizaciju rasa domaćih životinja i stanovništva. Na ovaj način, stepen sličnosti ili razlike unutar i između rasa može da se utvrdi, a ove razlike ili sličnosti su važne za genetsko unapređenje životinja. Dobijeni podaci o frekvencijama gena i genotipovima kroz studije polimorfizma čine mogućim ne samo poređenje gena životinja, mogućih uticaja gena na reproduktivne i performanse osobina, već i ispitivanje genetičke varijabilnosti pod različitim uslovima životne sredine selekcije. Ova studija je sprovedena sa ciljem da razmotri polimorfizam hemoglobina (Hb) u odabranim vrstama domaćih životinja sa ciljem pronalaženja tipa polimorfizma posmatrano preko elektroforeze na skrob gelu, usled varijacije u sekvenci amino kiselina u polipeptidnim lancima Hb. Pregledni rad jasno pokazuje da postoji diverzitet pod kontrolom gena u različitim vrstama domaćih životinja. To bi moglo da posluži kao referentna tačka za buduće studije namenjene unapređenju životinja možda korišćenjem selekcije pomoću markera.

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