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## SERUM PROTEIN ELECTROPHORESIS AS A VALUABLE FORENSIC TOOL FOR ANIMAL SPECIES IDENTIFICATION

(With 4 Tables and 4 Figures)

By

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التحليل الكهربائي لبروتين مصلى الدم كوسيلة تشخيصية للتفريق بين الفصائل  
الحيوانية المختلفة في مجال الطب الشرعي

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في هذه الدراسة تم فحص ١٦ فصيلة حيوانية لمعرفة المكونات المختلفة لبروتين مصلى الدم (بري-البيومين والبيومين وجلوبيولين ومكونات الجلوبيولين). تم تجميع مصلى الدم من الفصائل الحيوانية المختلفة السليمة إكلينيكيًا (الأبقار والجاموس والجمال والأغنام والماعز والأرانب والخيول والحمير والبغال والكتاكتيت والرومي والحمام والكلاب والقطة والجرذان والفئران البيضاء). تم حساب القيمة النسبية والحقيقية لمكونات بروتين مصلى الدم وكذلك حساب نسبة الألبومين/الجلوبيولين. وقد أسفرت النتائج أن بروتين مصلى الدم قد انفصل بواسطة التحليل الكهربائي باستخدام أسينات السليولوز إلى مكونات أساسية علي النحو الآتي:

- ١- أربع مكونات (البيومين وألفا وبيتا وجاما جلوبيولين) في الأبقار والجاموس .
  - ٢- ست مكونات (البيومين وألفا ١ وألفا ٢ وبيتا ١ وبيتا ٢ وجاما جلوبيولين) في الجمال والأرانب والخيول والحمير والبغال.
  - ٣- سبع مكونات (البيومين وألفا ١ وألفا ٢ وبيتا ١ وبيتا ٢ وجاما ١ وجاما ٢ جلوبيولين) في الأغنام والقطة والكلاب.
  - ٤- خمس مكونات (البيومين وألفا وبيتا ١ وبيتا ٢ وجاما جلوبيولين) في الماعز .
  - ٥- سبع مكونات (بري-البيومين والبيومين وألفا ١ وألفا ٢ وبيتا ١ وبيتا ٢ وجاما جلوبيولين) في الكتاكتيت والرومي والحمام.
  - ٦- خمس مكونات (البيومين وألفا ١ وألفا ٢ وبيتا وجاما جلوبيولين) في الجرذان والفئران البيضاء.
- وقد أوضحت نسبة الألبومين إلى الجلوبيولين وجود فرق بين هذه الفصائل الحيوانية المختلفة.

ومما سبق ذكره من مكونات بروتين مصد الدم المختلفة في هذه الفصائل التي تم دراستها أنه يمكن استخدام اختلاف هذه المكونات وكذلك اختلاف نسبة الألبومين إلى الجلوبيولين كوسيلة تشخيصية للتفريق بين هذه الفصائل الحيوانية وخاصة في مجال الطب الشرعي.

## SUMMARY

Sixteen animal species were investigated to define the reference values of different serum protein constituents (pre-albumin, albumin, globulin and globulin fractions). Serum samples were obtained from clinically healthy animal species (cows, buffaloes, camels, sheep, goats, rabbits, horses, donkeys, mules, chicken, turkeys, pigeons, dogs, cats, albino mice and albino rats), 5 samples from each species. The relative (%) and absolute values of the electrophoretic fractions of serum proteins were determined using cellulose acetate electrophoresis technique. Albumin/globulin ratio was also calculated. The obtained results revealed that protein fractions were clearly resolved into: (1) four fractions (albumin,  $\alpha$ -,  $\beta$ - and  $\gamma$ -globulin) in cows and buffaloes. (2) Six fractions (albumin,  $\alpha_1$ -,  $\alpha_2$ -,  $\beta_1$ -,  $\beta_2$ - and  $\gamma$ -globulin) in camels, rabbits, horses, donkeys and mules. (3) Seven fractions (albumin,  $\alpha_1$ -,  $\alpha_2$ -,  $\beta_1$ -,  $\beta_2$ -,  $\gamma_1$ - and  $\gamma_2$ -globulin) in sheep, dogs and cats. (4) Five fractions (albumin,  $\alpha$ -,  $\beta_1$ -,  $\beta_2$ - and  $\gamma$ -globulin) in goats. (5) Seven fractions (pre-albumin, albumin,  $\alpha_1$ -,  $\alpha_2$ -,  $\beta_1$ -,  $\beta_2$ - and  $\gamma$ - globulin) in chicken, turkeys and pigeons. (6) Five fractions (albumin,  $\alpha_1$ -,  $\alpha_2$ -,  $\beta$ - and  $\gamma$ -globulin) in albino mice and rats. The albumin/globulin ratio of the investigated animal species indicated difference between each others. The reference values of the protein fractions which defined herein as well as albumin/globulin ratio could be used as a diagnostic tool for animal species identification in the field of forensic medicine.

**Key words:** *Forensic medicine - animal species identification - cellulose acetate electrophoresis.*

## INTRODUCTION

The electrophoretic technique is the current standard of reference for the fractionation of the serum proteins in clinical biochemistry. The marked advances in technology of the past decade have made this previously elaborate technique into a widely used, routine clinical biochemical test procedure. Its current widespread use is commensurate with its reflection of a variety of changes in serum protein patterns in

disease. Although only a few changes in pattern can be considered as diagnostic of specific disease, the results of electrophoresis, properly interpreted, can be one of the most useful diagnostic aids (Kaneko, 1997).

There are well over 200 plasma proteins described and quantitated mainly in diseased man and many of which change only subtly or not at all. The proteins of an individual or of a species are synthesized under genetic control, it would be expected that variations in proteins would occur between individuals and between species. These variations are reflected in the species differences of the normal serum protein electrophoresis (SPE) patterns. Thus, in ruminants such as the cow, the normal SPE pattern exhibits an albumin, one  $\alpha$ , one  $\beta$  and one  $\gamma$  fraction of globulin (Kaneko, 1997).

Routine serum protein electrophoresis is recognized as the most reliable assessment of animal protein profiles in health and disease and has replaced biochemical determination of albumin and A/G ratio in the ability to predict abnormalities of clinical significance. The importance of considerable species differences to overall interpretation of animal electrophoresis is well established and constitutes a continued challenge to the veterinarians and to the providing laboratories to continue the pursuit of species-specific, even age- and gender-specific, reference ranges. Patterns of various diseases continue to emerge as more scrutiny is applied to use this tool in animal diagnostics for overall health assessment as an adjunct to specific disease diagnosis and for both prognostic and therapeutic monitoring. Electrophoresis has applications in biology, biochemical research, protein chemistry, pharmacology, forensic medicine, clinical investigations, veterinary science and food quality control.

Protein electrophoresis can be performed on either serum or plasma. Serum is generally preferred because the fibrinogen in plasma will often obscure the electrophoretogram in the  $\beta$ - $\gamma$  region (Tietz, 1987). With electrophoresis, proteins are separated based on their migration rate in an electrical field. The rate of migration depends on the charge and the size of protein, the strength of the electrical field, and the medium through which the proteins are migrating (Kaneko, 1997). The rate of proteins migration will be affected by the pH and the ionic strength as well as composition of the buffer system used (Tietz, 1987; Kaneko, 1997). The standard buffer is barbital pH 8.6 at which the majority of plasma proteins will carry a negative charge (Kaneko, 1997). The

medium of choice for routine diagnostic purpose is either agarose (Baker and Valli, 1988; Matthews, 1982) or cellulose acetate (Kaneko *et al.*, 1997) because each is relatively simple to use and provides accurate results. Other media that can be used include starch or polyacrylamide gel.

Serum albumin, SA is the major plasma protein, fulfilling several physiological functions: as transport molecule (for fatty acids, bilirubin, hormones, drugs, ions), in colloid osmotic regulation, and as easily accessible protein reserve (Andersson, 1979). In humans, nutrition, stress, altered hormonal balance and liver diseases are known to affect SA levels, causing major disorders (Birke *et al.*, 1979). General investigations on animal serum albumin are rare, and protein or sequence data are available only for a few species (Doolittle, 1984; Brown *et al.*, 1989; Sargent *et al.*, 1981).

Species identification by electrophoresis is routinely used in the food industry in order to prove adulterations, especially of meat (Bauer and Hofmann, 1987), fish (Rehbein, 1992) or dairy products (Mayer and Hoertner, 1992). In forensic sciences, unknown blood samples are often (Divall, 1985; Righetti *et al.*, 1991), but not necessarily identified by electrophoretic methods. Protocols based on protein reactivity with specific antibodies (Benjamin *et al.*, 1987) or DNA analysis (Gill, 1989) are preferred for special human applications (e.g. distinguish between individuals).

The principal aim of this study was to establish general protein patterns of serum samples of different healthy animal species and to compare between them as a useful tool for species differentiation using cellulose acetate electrophoretic technique.

## **MATERIALS and METHODS**

Sixteen animal species were investigated in this study. Blood samples were obtained by jugular puncture and were allowed to clot at room temperature. Serum samples were obtained from clinically healthy individuals of different animal species (5 samples from each species) as following: Cows (balady), buffaloes, camels, sheep, goats, rabbits, horses, donkeys, mules, chicken (meat producing chicken), turkeys, pigeons, dogs, cats, albino rats, and albino mice. Serum samples harvested and stored at -4°C until analyzed by cellulose acetate

electrophoresis. All hemolyzed or lipemic samples were discarded and another samples were collected.

**(A) Determination of total serum protein:**

Total protein was determined by the Biuret method as described by Kachmar (1970).

**(B) Electrophoretic patterns of serum protein:**

Serum proteins were electrophorsed according to the procedure of Helena Laboratories Publications (Kohn, 1958). Titan III Cellulose Acetate Plates, Electra HR buffer, and Ponceau S stain were used. The electrophoretic patterns of serum proteins were scanned and graphed by Auto-Scanner Flur-Vis to reveal the densitometer tracings.

## RESULTS

The obtained results were summarized in Figures 1 - 4 and Tables 1 - 4.

## DISCUSSION

Hematochemistry constitutes an increasingly useful aid in zootechnical and veterinary research. It permits the study of specific pathological alterations of certain blood constituents and recognition, under strictly controlled experimental conditions, of the existence of metabolic alterations of different origin. Many factors can influence the level of a particular blood constituents: genetic type, feeding, macro- and micro-environment, rearing technique, age, physiological state and sex as well as pathological factors. Moreover, methods of sampling and obtaining the biological material and the method of analysis can also influence the results.

Proteins in the blood of mammals contain fractions which have been identified as albumin, alpha, beta and gamma globulin. Each main fraction consists of subfractions which exhibit individual and genetically determined variation (Andersen, 1984). It has been reported that different species of animals have characteristic protein profiles (Phillis, 1976). Albumin/globulin ratio was reported to be varied according to the species of animal (Kaneko *et al.*, 1997).

Serum contains a variety of small molecules, as well as hundreds of different serum proteins. Serum proteins are frequently separated and characterized by electrophoresis in the clinical laboratory to determine

the concentration of various proteins and to detect abnormal protein species.

Serum albumin is the major plasma protein in quite a number of species and thought to be a protein undergoing rather rapid evolutionary changes (Doolittle, 1984). All animals investigated in this study were mammals, except the chicken, pigeon and turkeys. Most mammalian serum albumin had rather similar electrophoretic behavior.

Figures 1 and 3 show that cow's and buffalo's serum resolved into albumin and single alpha ( $\alpha$ ), beta ( $\beta$ ) and gamma ( $\gamma$ ) globulin zones. The obtained results in this study for electrophoretogram of serum protein of cattle and buffaloes are in agreement with that recorded by Schalm *et al.* (1975); Yoshida (1986,1991) and Kaneko *et al.* (1997).

In the present study (Table 1), the absolute concentration (g/l) of total serum protein, albumin and globulin were 70.93, 32.58 and 38.35 for cows, and 73.64, 36.63 and 37.01 for buffaloes. The relative concentrations (%) of globulin fractions (Table 2) ( $\alpha$ ,  $\beta$  and  $\gamma$ ) were 14.93, 17.72 and 21.42 for cows, and 12.76, 15.95 and 21.54 for buffaloes. Albumin/globulin ratio (A/G ratio) was 0.85 and 0.99 in cows and buffaloes respectively. On the absolute basis (g/l) these globulin fractions were  $\alpha$  (10.59),  $\beta$  (12.57) and  $\gamma$  (15.19) for cows, and  $\alpha$  (9.4),  $\beta$  (11.75) and  $\gamma$  (15.85) for buffaloes.

Today, the fractionation of serum proteins by means of zone electrophoresis with cellulose acetate membrane is performed as a routine work for clinical diagnosis. This electrophoresis is highly efficient in separating the serum proteins in a short time and dealing with many samples at ones. Electrophoresis with cellulose acetate membrane make it possible to separate the serum proteins in animals. Excellent electrophorograms produced by it have been presented for dogs (Fukuda and Shibanaï, 1971) and horses (Berrier, 1969). The serum proteins of cattle, however, have not clearly fractionated. Especially,  $\alpha$ -globulin has not been separated into two fractions,  $\alpha_1$  and  $\alpha_2$  as yet. Furthermore, the diagnostic significance of changes in  $\alpha_1$  and  $\alpha_2$  has been clarified in human medicine (Hirayama *et al.*, 1964). Therefore, it considerably significant for a clinical diagnosis in cattle to divide  $\alpha$ -globulin into  $\alpha_1$ - and  $\alpha_2$ -globulin (Kawamura *et al.*, 1974).

Serum proteins of cattle has hardly been observed that  $\alpha$ -globulin was divided into two fractions,  $\alpha_1$ - and  $\alpha_2$ -globulin, and that  $\beta$ - and  $\gamma$ -globulin were separated clearly from each other. In dogs (Fukuda and Shibanaï, 1971) and horses (Mattheeuws *et al.*, 1966), the serum proteins

have been divided distinctly into 5 or 6 fractions, such as albumin,  $\alpha_1$ -,  $\alpha_2$ -,  $\beta_1$ -,  $\beta_2$ - and  $\gamma$ -globulin. It is generally assumed that the low separation of the serum proteins in cattle and buffaloes may be attributed to the high viscosity and the small difference in isoelectric point among the protein fractions of serum. By vertical electrophoresis with polyacrylamide gel, however, the  $\alpha$ - globulin fractions of cattle are divided into two parts (Schmidt, 1968). Ek (1969) reported that use of a modified buffer solution containing 0.38 g of calcium acetate in 1.0 L of barbital buffer solution and by use calcium lactate, 3 gm (Kawamura *et al.*, 1974), it was clearly possible to separate  $\beta$ -globulin from  $\gamma$ -globulin, but not to divide  $\alpha$ - globulin into two fractions. From the results obtained by Kawamura *et al.* (1974), it is presumed that even  $\alpha$ -globulin of bovine serum may be separated into  $\alpha_1$ - and  $\alpha_2$ -globulin by using modified buffer barbital solution containing 1 gm and 2 gm calcium lactate.

Kawamura (1974) reported that the total serum protein was 75 g/l and the relative values (%) of its fractions in the cattle by using cellulose acetate electrophoresis technique were: albumin (44.9),  $\alpha_1$ -globulin (6.8),  $\alpha_2$ -globulin (11.3),  $\beta$ -globulin (10.5),  $\gamma$ -globulin (24.9), and A/G ratio was 0.86. Yoshida (1986) reported that the total protein was 72.7 g/l and the absolute concentration (g/l) of serum protein fractions of the cattle by using cellulose acetate electrophoresis technique were: albumin (35.8),  $\alpha$ -globulin (9.9),  $\beta$ -globulin (6.3),  $\gamma$ -globulin (20.5), and A/G ratio was 0.97. Yoshida (1991) reported the total protein was 72.3 g/l and the absolute concentration (g/l) of serum protein fractions in cattle by using cellulose acetate electrophoresis technique were: albumin (35.6),  $\alpha$ - globulin (9.9),  $\beta$ - globulin (6.4),  $\gamma$ - globulin (20.3), and A/G ratio was 0.97. Kaneko *et al.* (1997) reported that the total protein was 71 g/l and the absolute concentration (g/l) of serum protein fractions in cattle by using cellulose acetate electrophoresis technique were: albumin (32.9), total globulin (38.1), and A/G ratio was 0.86. Shrikhand and Sarode (1999) found that total serum protein of cows was 72.5 g/l, albumin was 33.7 g/l and globulin was 38.3 g/l and A/G ratio was 0.87.

Inspite of the several studies performed on the blood constituents of the dromedary (one-humped), little information is available concerning the electrophoretic pattern of the serum proteins. The results obtained in this study (Table 1) showed that the absolute concentration (g/l) of total serum protein, albumin and globulin were 69.18, 33.64 and 35.54 in camels respectively. The relative values (%) (Table 2) of

globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) were 5.31, 7.53, 6.69, 7.82 and 24.03 respectively. A/G ratio was 0.95. Previous works on camel serum showed that it resolved into single alpha, beta and gamma globulin zones (Boyd *et al.*, 1980 and Abdo *et al.*, 1987) which are differ from the results obtained in the present study (where it resolved into  $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$  zones). Abdo *et al.* (1987) reported that the electrophoretic pattern of serum protein and its fractions in camel by using cellulose acetate strips electrophoresis technique showed that: total protein (58.2 g/l), albumin (62%),  $\alpha$ -globulin. (2%),  $\beta$ -globulin (15.4%),  $\gamma$ -globulin (20%), and A/G ratio was 1.38. The obtained results in this study for dromedary (one-humped) are in- agreement with those reported for other species. In this study, the electrophoretic patterns of all investigated serum proteins for ovine, bovine, feline and poultry showed that globulin predominates over albumin. In horses, cows, dogs, cats, rabbit, the relative proportion of albumin to globulin are nearly equal (Wesibroth *et al.*, 1974; Swenson, 1984 and Kaneko *et al.*, 1997). The results therefore indicate species differences concerning the proportion of albumin and globulin. It had been also reported that not only the difference in the species of animals can affect the concentration and distribution of blood proteins but also the difference in the breed of one species have a relevant effect as reported in cattle (Balmacida and Bottari (1974), turkeys (Al-Heeti *et al.*, 1985), and chickens (Ross *et al.*, 1978).

In the present study (Table 1), the absolute concentrations (g/l) of total serum protein, albumin and globulin were 71.25, 30.51 and 40.74 for sheep, and 64.24, 30.41 and 33.83 for goats. The relative concentrations (%) (Table 2) of globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$ ,  $\gamma_1$  and  $\gamma_2$ ) were 7.11, 8.89, 10.25, 11.13, 14.72 and 5.08 respectively in sheep. In goats, globulin fractions ( $\alpha$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) were 9.48, 11.96, 8.56 and 22.67 respectively. A/G ratio was 0.75 and 0.90 in sheep and goat respectively. On the absolute basis (g/l) these globulin fractions in sheep were  $\alpha_1$  (5.06),  $\alpha_2$  (6.34),  $\beta_1$  (7.30),  $\beta_2$  (7.94),  $\gamma_1$  (10.48) and  $\gamma_2$  (3.62). Our obtained results are in-agreement with that observed by Dobson (1966), Fox *et al.* (1970) and Kaneko *et al.* (1997). Fox *et al.* (1970) found that sheep total protein was 72 g/l and absolute concentration of its fractions were (g/l): albumin (38.1),  $\alpha_1$ -globulin (3.8),  $\alpha_2$ -globulin (7.3),  $\beta$ -globulin (9.1),  $\gamma$ -globulin (13.7), and A/G ratio was 1.12, while Kaneko *et al.* (1997) found that total serum protein was 72 g/l and the absolute concentration of its fractions in sheep by using cellulose acetate electrophoresis were (g/l): albumin (27), globulin total (44),  $\alpha$ -globulin



(5),  $\beta_1$ -globulin (10),  $\beta_2$ -globulin (7),  $\gamma_1$ -globulin (16),  $\gamma_2$ -globulin (8), and A/G ratio was 0.61. Turner and Wilson (1962) discussed the difficulties of comparing results of electrophoretic examination by different researchers. In most studies, paper electrophoresis was used; it defines fewer protein bands than does electrophoresis with cellulose acetate (Knight and Leek, 1973). By cellulose acetate electrophoresis, 6 protein fractions were separated in serum of lambs (Dobson, 1966).

For rabbits, the reported results in the present study (Table 1) revealed that the absolute concentrations (g/l) of total serum protein, albumin and globulin were 61.73, 28.56 and 33.17 respectively. In Table 2, the relative values (%) of different globulin fractions were  $\alpha_1$  (6.90),  $\alpha_2$  (5.13),  $\beta_1$  (8.75),  $\beta_2$  (6.08) and  $\gamma$  (26.87) respectively. A/G ratio was 0.86. On the absolute basis (g/l) these globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) were 4.62, 3.17, 5.40, 3.75 and 16.59 respectively. In comparison with the results obtained by Wesibroth *et al.* (1974), our results showed some decrease concentrations (g/l) of total protein, albumin and globulin (68, 32.2 and 35.8 respectively). The globulin fractions concentrations (g/l) were  $\alpha_1$  (4.9),  $\alpha_2$  (3.2),  $\beta$  (12.4) and  $\gamma$  (15.8), while A/G ratio was 0.90.

In the present study (Table 1 and 3), the absolute concentrations (g/l) of total serum protein, albumin and globulin were 69.75, 31.96 and 37.79 for horse, 52.93, 25.62 and 27.31 for donkey, and 56.19, 26.23 and 29.96 for mules. The relative concentrations (%) of globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) were 3.96, 9.99, 13.85, 8.59 and 17.79 for horse, 2.42, 10.17, 11.60, 8.50 and 18.91 for donkey, and 3.59, 10.45, 14.40, 6.25 and 18.63 for mules. A/G ratios were 0.85, 0.94 and 0.88 in horses, donkeys and mules respectively. On the absolute basis (g/l) these globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) in horse were 2.76, 6.97, 9.66, 5.99 and 12.41 respectively.

On the percentage basis (%), normal values for albumin and globulin fractions in horses varied as following according to Coffman (1968): albumin (43-47.3),  $\alpha_1$ -globulin (5.34-14),  $\alpha_2$ -globulin (9.9-18.41),  $\beta$ -globulin (9-22.6) and  $\gamma$ -globulin (14.28-19). On the absolute basis (g/L), normal values for albumin and globulin fractions varied as following according to Pierce (1975): albumin (22.7-31.4),  $\alpha_1$ -globulin (1.9-7.3),  $\alpha_2$ -globulin (6.5-10.9),  $\beta$ -globulin (12.8-20.9) and  $\gamma$ -globulin (8.2-17.6). Kaneko *et al.* (1997) reported that the total protein was 63.5 g/l and the absolute concentration and the range (g/l) of serum protein and its fractions in horse by using cellulose acetate electrophoresis

technique were: albumin (30.9), total globulin (33.3),  $\alpha_1$ -globulin (1.9),  $\alpha_2$ -globulin (6.5),  $\beta_1$ -globulin (9.2),  $\beta_2$ -globulin (5.7),  $\gamma$ -globulin (10), and A/G ratio was 0.91.

In the present study (Table 1 and 3), the results revealed that total serum protein in chicken was 53.2 g/l and the concentrations of protein fractions were (g/l): pre-albumin (5.41), albumin (21.28), total globulin (26.51) and A/G ratio was 0.80. On the relative basis (%), the values were: pre-albumin (10.16), albumin (40.01), total globulin (49.83),  $\alpha_1$  (6.89),  $\alpha_2$  (8.22),  $\beta_1$ (6.43),  $\beta_2$ (9.19), and  $\gamma$  (19.10). The results of the present study are in-agreement with that reported by Fukata *et al.* (1997), Kaneko *et al.* (1997), and dis-agreement with Sells (1976) who used the same technique of electrophoresis.

Sells (1976) reported that the concentration of total serum protein was 31 g/l and the relative value (%) of its fractions in chickens by using cellulose acetate electrophoresis technique were: albumin (53.1),  $\alpha$ -globulin (4.6),  $\beta$ -globulin (13.1),  $\gamma$ -globulin (29.2), and A/G ratio was 1.14. Fukata *et al.* (1997) found that total serum protein was 43.5 g/l with a range of 42.4 to 44.6 g/l, while albumin was 18.2 with a range of 17.4 to 19 g/l, total globulin was 25.3 g/l and A/G ratio was 0.72. Kaneko *et al.* (1997) found that total protein was 56 g/l, albumin was 25 g/l, globulin was 31 g/l and A/G ratio was 0.81.

For turkey the concentrations (g/l) of total serum protein, albumin and globulin (Table 1) were 51.73, 22.57 and 25.01. In the Table 3, the relative concentration (%) of different globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) were 7.12, 9.03, 8.27, 10.21 and 13.72 respectively. A/G ratio was 0.90. On the absolute basis (g/l) these globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) were 3.68, 4.67, 4.28, 5.28 and 7.10 respectively. By using cellulose acetate paper strips electrophoresis, Al-Heeti *et al.* (1985) found that total serum protein in turkeys was 62.6 g/l, and protein fractions were (g/l): albumin (32.3), globulin (30.1),  $\alpha_1$  (4.1),  $\alpha_2$  (8.2),  $\beta$  (9),  $\gamma$  (8.8), and A/G ratio was 1.06. Our results showed some depletion in total protein which reflected by decrease in both albumin and globulin concentrations when compared with the results of Al-Heeti *et al.* (1985). On the other hand pre-albumin zone is not detected by him.

The recorded results in the present study for pigeons (Table 1) showed that total serum protein was 48.35 g/l and the concentrations of its fractions were (g/l): pre-albumin (8.2), albumin (16.48) and total globulin (23.67). On the relative basis (%) in Table 3, the value of different globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) were 5.83, 6.52, 7.10,

12.14 and 17.37 respectively. A/G ratio was 0.70. On the absolute basis (g/l) these globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$ ) were 2.82, 3.15, 3.43, 5.87 and 8.4 respectively. These results were higher than that observed by Lumei and de Bruijne (1985) and Kaneko *et al.* (1997). Lumei and de Bruijne (1985) reported that the total protein (27), and the absolute concentration (g/L) of serum protein fractions of the normal pigeons by using cellulose acetate membrane electrophoresis technique as: pre-albumin (2.8), albumin (17.5),  $\alpha$ -globulin (2.29),  $\beta$ -globulin (4.3),  $\gamma$ -globulin (1.9), and A/G ratio was 1.84. And, Kaneko *et al.* (1997) which reported that the total protein concentration was 21 g/l and A/G ratio was from 1.5.

The results obtained in this study (Table 1) for electrophoretic pattern of normal dogs revealed that the concentration (g/l) of total serum protein was 56.82, albumin (26.7) and total globulin (30.12). In Table 4, the relative values (%) of different globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$ ,  $\gamma_1$  and  $\gamma_2$ ) were 4.51, 7.97, 6.46, 11.12, 13.27 and 9.68 respectively. A/G ratio was 0.87. The obtained results in the present study are in agreement with that recorded by Pickrell *et al.* (1974) and Kaneko *et al.* (1997). Pickrell *et al.* (1974) found that the relative value of serum protein fractions as: albumin (57.1),  $\alpha_1$  (8.4),  $\alpha_2$  (9.0),  $\beta_1$  (7.5),  $\beta_2$  (9.0),  $\gamma$  (9.3), and A/G ratio was graduated from 0.9 to 1.9. Kaneko *et al.* (1997) reported that the concentration (g/L) of serum protein and its fractions of the normal dogs by using cellulose acetate electrophoresis technique were: total protein (61), albumin (29.1), globulin (31.9), and A/G ratio was 0.91.

Serum electrophoresis is being used with increasing frequency in veterinary medicine as an aid patient evaluation. The ability to define protein fractions in greater detail than the division into albumin and globulin adds further description to many disease processes. Feline serum has been evaluated previously by agar gel, cellulose acetate, and paper electrophoretic techniques. Agar gel electrophoresis has been reported to result in a good resolution of 6 to 7 major bands, as well as definition of 1 to 3 minor bands (Gotz & Balogh, 1967). However, these reports did not name or define these fractions. Both paper and cellulose acetate electrophoresis have resulted in 6 major bands in some reports (Causse-Vaills *et al.*, 1961; Osbaldiston, 1972). Normal concentrations of serum protein fractions vary somewhat according to electrophoretic technique and the samples.

The present study (Table 1) revealed that the concentration (g/l) of total serum protein in examined cats was 62.36, albumin (25.41) and total globulin (36.95). In Table 4, the relative values (%) of different globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$ ,  $\gamma_1$  and  $\gamma_2$ ) were 6.31, 7.46, 8.60, 10.61, 11.47 and 14.80 respectively. A/G ratio was 0.69. On the absolute basis (g/l) these globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$ ,  $\gamma_1$  and  $\gamma$ ) were 3.94, 4.65, 5.26, 6.62, 7.15 and 9.23 respectively. The present results are nearly similar to that previously reported for normal cats (Osbaldiston, 1972; Barsanti & Hubbell, 1980; Kaneko *et al.*, 1997). Osbaldiston (1972) reported that the absolute concentration (g/L) of serum protein and its fractions of the normal cats by using cellulose acetate electrophoresis technique were: total protein (69), albumin (30),  $\alpha_1$ -globulin (6),  $\alpha_2$ -globulin (8),  $\beta_1$ -globulin (4),  $\beta_2$ -globulin (4) and  $\gamma$ -globulin (16.5). Barsanti and Hubbell (1980) reported that the relative and absolute concentration of serum protein and its fractions of the normal cats by using cellulose acetate electrophoresis technique were: total protein (72.1 g/L), albumin (41.3 %),  $\alpha_1$ -globulin (2.9 %),  $\alpha_2$ -globulin (16.3 %),  $\beta_1$ -globulin (4.9 %),  $\beta_2$ -globulin (6.8 %) and  $\gamma$ -globulin (27.6 %). Kaneko *et al.* (1997) found that total serum protein was 66 g/l, albumin 27 g/l, globulin 39 g/l, and A/G ratio was 0.71. Our results in this study are in agreement with Kaneko *et al.* (1997) who recorded that globulin was resolved into six zones as  $\alpha_1$ ,  $\alpha_2$ ,  $\beta_1$ ,  $\beta_2$ ,  $\gamma_1$  and  $\gamma_2$  as we found.

The absolute concentrations (g/l) of total serum protein, albumin and globulin of albino mice (Table 1) were 64.31, 26.72 and 37.59 respectively. The relative value (%) in Table 4 for globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta$  and  $\gamma$ ) were 10.45, 15.60, 18.58 and 13.82. On the absolute basis (g/l) these globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta$  and  $\gamma$ ) were 6.72, 10.03, 11.95 and 8.89. A/G ratio was 0.71. These results showed some differences than that reported by Finch and Foster (1973), and Kaneko *et al.* (1997). Finch and Foster (1973) who recorded that total serum protein was 62 g/l, and that for protein fractions were (g/l): albumin (31.4),  $\alpha_1$  (5.3),  $\alpha_2$  (9.1),  $\beta$  (10.4), and  $\gamma$  (6.1), while A/G ratio was 1.02, and Kaneko *et al.* (1997) which found that total serum protein was 62 g/l and the absolute concentration (g/L) of protein fractions of the normal albino mice by using cellulose acetate electrophoresis technique were: albumin (34), globulin (28), and A/G ratio was 1.21.

In Table 1, the concentrations (g/l) of total serum protein, albumin and globulin of albino rats were 76.23, 33.86 and 42.37. The relative

value (%) for globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta$  and  $\gamma$ ) were 14.08, 10.51, 14.39 and 16.60 respectively (Table 4). On the absolute basis (g/l) these globulin fractions ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta$  and  $\gamma$ ) were 10.73, 8.01, 10.97 and 12.66. A/G ratio was 0.80. The results showed some similarity when compared with the results of Nomura *et al.* (1975), Marino *et al.* (1976) and Kaneko *et al.* (1997). Nomura *et al.* (1975) found that total protein was 76.1 g/l and the protein fractions in normal albino rat were (g/l): albumin (37.3),  $\alpha_1$ -globulin (10.3),  $\alpha_2$ -globulin (7.1),  $\beta$ -globulin (10.7),  $\gamma$ -globulin (10.5) and A/G ratio was 0.96 with a range of 0.72 to 1.21. Marino *et al.* (1976) reported that the relative values (%) of serum protein fractions of the Sprague Dawley rat by using cellulose acetate electrophoresis as: albumin (49.1),  $\alpha$ -globulin (27.2),  $\beta$ -globulin (14),  $\gamma$ -globulin (9.6) and A/G ratio was 0.96. Kaneko *et al.* (1997) reported that total serum protein was 75.2 g/l and its fractions of the normal albino rat by using cellulose acetate electrophoresis technique were (g/l): albumin (41.7), globulin (33.5), and A/G ratio was 1.24.

Normal values of biochemical constituents of blood and serum in animals are of academic as well as clinical importance. Extensive research revealed that these values vary from region to region. It is therefore, necessary to establish the normal levels of biochemical constituents of blood and serum in animals of particular region. The obvious difference of total serum protein, albumin, and globulin recorded in the present study, is considered a helpful index in differentiation between different animal species.

## REFERENCES

- Abdo, M.S.; Hassanien, M.M.; Manna, M.E. and Hamed, M. (1987): Electrophoretic pattern of serum proteins in the Arabian Camel. *Indian Vet. J.*, 64: 841-844.
- Al-Heeti, H.E.; Al-Soudi, K.A. and Mehdi, A.W.R. (1985): Serum proteins of three turkey strains under different seasonal conditions. *Poultry Sci.*, 64: 1363-1367.
- Andersson, L. (1979): Plasma proteins. Blombaeck, B.; Hanson, L.A. and Winberg, H. (eds), John Wiley, Chichester, pp. 43-54.
- Andersen, E. (1984): Blood groups, immunogenetics and biochemical genetics. Chapter 4, Dukes "physiology of domestic animals. Swenson, M.T. (ed). 10<sup>th</sup> Ed. Comstock publishing Associates, A division of Cornell University press, Ithaco and London.

- Balmacida, R.A. and Bottari, C.V. (1974):* *Revta Med. Vet. Aire.* 55:1.(Cited after *Abdo et al.*, 1987).
- Baker, R.J. and Valli, R. (1988):* Electrophoretic and immunoelectrophoretic analysis of feline serum proteins. *Can. J. Vet. Res.*, 52: 308- 314
- Barsanti, J.A. and Hubbell, J. (1980):* Serum proteins in normal cats and cats infected with *Aelurostrongylus abstrusus*. *Am. J. Vet. Res.*, 41(5): 775-778.
- Bauer, F. and Hofmann, K. (1987):* 3<sup>rd</sup> International Congress of Meat Science & Technology (European Meeting of Meat Research Workers), Proceeding Vol. 2, Helsinki, pp. 364-367.
- Benjamin, D.C.; Herr, J. C.; Sutherland, W.M.; Woodward, M.P.; Decourey, K. and Condon, T.P. (1987):* A unique epitope on human serum albumin recognized by monoclonal antibody HSA-1: A probe for identification of the human origin of blood or tissue. *Hybridoma*, 6:183-190.
- Berrier, B.W. (1969):* Electrophoretic analysis of blood serum and plasma proteins of normal horses. *Amer. J. Vet. Res.*, 30: 2237-2240.
- Birke, G.; Liljedahl, S. and Rothschild, M. (1979):* Plasma proteins. John Wiley, Chichester, pp. 54-71.
- Boid, R.; Luckins, A.G.; Roe, P.F.; Gray, A.R; Mahmoud, M.M. and Malik, K.N. (1980):* *Veterinary Parasitology*, 6 :333. (Cited after *Abdo et al.*, 1987).
- Brown, W.M.; Dziegieliewska, K.M.; Foremman, R.C. and Saunders, N.R. (1989):* Nucleotide and deduced amino acid sequence of sheep serum albumin. *Nucleic Acids Res.*, 17(24): 10495.
- Causse-Vaills, M.; Verain, A. and Verain, A. (1961):* Electrophorese sur papier du serum de chat. *CR Acad. Sci. [D] (Paris)*, 252: 2453-2455.
- Coffman, J.R. (1968):* Clinical application of serum protein electrophoresis of horse. *Proc. 14<sup>th</sup> Ann. Meeting. AAEP.* pp. 265-279.
- Divall, G.B. (1985):* *Electrophoresis*, 6:249-258. (Cited after *Miller et al.*, 1995).
- Dobson, C. (1966):* Cellulose acetate electrophoresis of the serum proteins of sheep: A study of developmental changes in young lambs. *Austral. J. Exptl. Biol. and Med. Sci.*, 44: 575-580.

- Doolittle, R.F. (1984):* The plasma proteins. Structure, Function and Genetic control. Putnam, F.W. (Ed), Vol. IV, 2<sup>nd</sup> Ed., Academic press, New York, pp. 317-360.
- Ek, N. (1969):* Studies on electrophoresis on cellulose acetate membrane of bovine serum proteins in healthy animals. Acta Vet. Scand., 10: 118-126.
- Finch, C.E. and Foster, J.R. (1973):* Hematologic and serum electrolyte values of the C57BL/6J male mouse in maturity and senescence. Lab. Animal Sci., 23 (3): 339-349.
- Fox, R.R.; Laird, C.W.; Blau, E.M. ; Schultz, H.S. and Mitchell, B.P. (1970):* Biochemical parameters of clinical significance in rabbits, I strain variation and II Diurnal variation. J. heredity, 61:267.
- Fukuda, Y. and Shibani, D. (1971):* Cellulose acetate membrane electrophoretic studies on serum plasma protein in dogs. Bull. Fac. Agric., Yamaguti Univ., No 22,393-412.
- Fukata, T.; Komba, Y.; Sasai, K.; Baba, E. and Arakawa, A. (1997):* Evaluation of plasma chemistry and hematological studies on chickens infected with Eimeria tenella and E. Acervulina. Vet. Rec., 141: 44-46.
- Gill, P. (1989):* Adv. Electrophoresis, 3:405-444. (Cited after Miller *et al.*, 1995).
- Gotz, H. and Balogh, R. (1967):* Die serum proteine des Tieres. Zentralbl. Veterinarmed. [A], 14: 385-394.
- Hirayama, C.; Fukuda, T.; Yoshikawa, T. and Koga, S. (1964):* Metabolism of plasma proteins. Metabolism and Disease, I: 572-581.
- Kachmar, T.F. (1970):* Protein and amino acids. In: Fundamentals of Clinical Chemistry. N.W. Tietz (ed.), W.B. Saunders Co. Philadelphia, PA .pp. 177-255.
- Kaneko, J.J. (1997):* Serum proteins and the dysproteinemias. In: Clinical Biochemistry of Domestic Animals. 5<sup>th</sup> Ed., San Diego, Academic Press, pp. 117-138.
- Kaneko, J.J.; Harvey, J.W. and Bruss, M.L. (1997):* Serum proteins and the dysproteinemias. In: Clinical Biochemistry of Domestic Animals. 5<sup>th</sup> Ed., San Diego, Academic Press, pp. 117-138.

- Kawamura, S.; Yasuda, Y.; Tayama, H.; Moki, H.; Takasse, K. and Ogasawara, S. (1974):* Cellulose acetate membrane electrophoresis of bovine serum proteins using a barbital calcium buffer. *Jap. J.Vet.Sci.*, 36: 285-290.
- Knight, R.A. and Leek, R.G. (1973):* Electrophoresis of serum proteins on cellulose acetate: Comparison of bottle-raised versus ewe-raised lambs from birth to 19 weeks of age. *Am. J. Vet. Res.*, 34(5): 701-703.
- Kohn, J. (1958):* A micro-electrophoretic method. *Nature*, 181: 838-844.
- Lumei, J.T. and de Bruijne, J.J. (1985):* Blood chemistry reference values in racing pigeons *Columbo Livia Domestica*). *Avian Pathology*, 14: 401-408.
- Marino, A.A.; Berger, T.J.; Austin, B.P. and Becker, R.O. (1976):* Evaluation of electrochemical information transfer system. I. Effect of electric fields on living organisms. *J. Electrochem. Soc.*, 123: 1199-1200.
- Mattheeuws, D.R.G.; Kaneko, J.J.; Loy, R.G., Cornelius, C.E. and Wheat, J.D. (1966):* Compartmentalization and turnover of I<sup>131</sup>-labeled albumin and gamma globulin in horse. *Amer. J. Vet. Res.*, 27: 699-705.
- Matthews, A.G. (1982):* Serum protein electrophoresis in horses and ponies. *Equine Vet. J.*, 14: 322-324.
- Mayer, W. and Hoertner, H. (1992):* Discontinuous electrophoresis of beta-caseins for the determination of bovine caseins in milk and dairy products. *Electrophoresis*, 13; 803-804.
- Miller, I., Gutleb, A.C. and Gemeiner, M. (1995):* Two-dimensional electrophoresis for the study of blood/serum proteins of the otter, an endangered species. *Electrophoresis*, 16: 1193-1198.
- Nomura, G.; Tamura, M.; Hirhashi, K. and Nagasi, S. (1975):* Comparison of Constituents of Blood of Several Experimental Animals with Human Blood. *Experimental Animals (Tokyo)* 22: 321.
- Okoshi, S.; Tomoda, I. and Makimura, S. (1968):* Analysis of normal cat serum by immunoelectrophoresis. *Jpn. J. Vet. Sci.*, 29: 337-345.
- Osbaldiston, G.W. (1972):* Serum protein fractions in domestic animals. *Brit. J.*, 128: 386-393.
- Phillis, J.W. (1976):* *Veterinary Physiology*, Wright-scientchnica.Bristol.



- Pickrell, A.; Schluter, S.J.; Belasich, J.J.; Stewart, E.V.; Hobbs, C.H. and Jones, R.K. (1974):* Relationship of age of normal dogs to blood serum constituents and reliability of measured single values. *Am. J. Vet. Res.*, 35(7): 897-903.
- Pierce, K.R. (1975):* Assay of equine serum proteins by clinical chemistry and electrophoretic methods. *Proc. AAEP. I<sup>st</sup> Intl. Symposium in Clinical Hematology.* pp. 144-151.
- Rehbein, H. (1992):* Fish species identification by peptide mapping of the myosin heavy chain. *Electrophoresis*, 13:805- 806.
- Righetti, P.G.; Gianazza, E.; Bianchi-Bosisio, A.; Sinha, P. and Koettgen, E. (1991):* Isoelectric focusing in immobilized pH gradients: applications in clinical chemistry and forensic analysis. *J. Chromatogr.*, 569: 197-228.
- Ross, J.G.; Christie, G.; Halliday, W.G. and Morley Jones, R. (1978):* Hematological and blood chemistry "Comparison values" for clinical pathology in poultry. *Vet. Rec.*, 102: 29-31.
- Sargent, T.D.; Yang, M. and Bonner, J. (1981):* Nucleotide sequence of cloned rat serum albumin messenger RNA. *Proc.Natl.Acad.Sci.USA*, 78: 243-246.
- Schalm, O.W.; Jain, N.C. and Carroll, E.J. (1975):* The plasma proteins. In: *Hematology.* Lea and Febiger, Philadelphia, pp. 602-630.
- Schmidt., J. (1968):* Differentiation of animal protein by vertical electrophoresis in polyacrylamide gel. I. Technique and bovine serum proteins. *Deut. Tierartl. Wschr.*, 75: 87-91.
- Sells, D.M. (1976):* Progressive changes in serum proteins and the rheumatoid factor of chickens infected with mycoplasma synoviae. *Avian Diseases*, 20 (1): 108-117.
- Shrikhande, G.B. and Sarode, D.B. (1999):* Haematobiochemical levels in cows of different age groups. *Indian Vet. J.*, 76: 38-40.
- Swenson, M.J. (1984):* Dukes " physiology of domestic animals. Swenson, M.T.(ed). 10<sup>th</sup> Ed. Comstock publishing Associates, A division of cornell University press, Ithaco and London.
- Tietz, N.W. (1987):* Fundamentals of clinical chemistry. 3<sup>rd</sup>, Philadelphia: WB Saunders. pp. 317- 319.
- Turner, J.H. and Wilson, G.I. (1962):* Serum protein studies on sheep and goats. I: Studies on shropshire lambs exposed to different degrees of parasitism. *Am. J. Vet. Res.*, 23: 718-724.
- Wesibroth, S.H.; Flatt, R.E. and Kraus, A.L. (Eds) (1974):* Biology of the Laboratory Rabbit. New York, Academy press Inc., p552.

*Yoshida, Y. (1991):* Electrophoretic studies on serum proteins in cows with trumatic pericarditis. J.Vet.Med.Sci., 53(1): 5-11.

*Yoshida, Y. (1986):* Levels of serum protein, protein fractions and minerals in dairy cow with trumatic gastritis of various conditions. Jpn. J. Vet. Sci., 48(6): 1153-1159.

**Table 1: Total protein, albumin and globulin values (g/L), and relative value (%) of albumin and globulin and their ratio in different animal species.**

Animal species	Absolute value (g/l)			Relative value (%)		A/G ratio
	Total protein	Albumin	Globulin	Albumin	Globulin	
Cows	70.93 ± 1.11	32.58 ± 0.51	38.35 ± 0.60	45.93 ± 0.72	54.07 ± 0.84	0.85
Buffaloes	73.64 ± 0.98	36.63 ± 0.49	37.01 ± 0.50	49.75 ± 0.66	50.25 ± 0.67	0.99
Camels	69.18 ± 0.32	33.64 ± 0.15	35.54 ± 0.16	48.62 ± 0.22	51.38 ± 0.24	0.95
Sheep	71.25 ± 0.91	30.51 ± 0.42	40.74 ± 0.52	42.82 ± 0.42	57.18 ± 0.73	0.75
Goats	64.24 ± 0.7	30.41 ± 0.33	33.83 ± 0.36	47.33 ± 0.51	52.67 ± 0.56	0.90
Rabbits	61.73 ± 0.23	28.56 ± 0.10	33.17 ± 0.12	46.27 ± 0.17	53.73 ± 0.19	0.86
Horses	69.75 ± 0.78	31.96 ± 0.36	37.79 ± 0.41	45.82 ± 0.50	54.18 ± 0.60	0.85
Donkeys	52.93 ± 0.38	25.62 ± 0.18	27.31 ± 0.19	48.40 ± 0.34	51.60 ± 0.36	0.94
Mules	56.19 ± 0.62	26.23 ± 0.28	29.96 ± 0.33	46.68 ± 0.51	53.32 ± 0.58	0.88
Chicken	53.20 ± 0.16	21.28 ± 0.06	26.51 ± 0.08	40.01 ± 0.12	49.83 ± 0.15	0.80
Turkeys	51.73 ± 0.18	22.57 ± 0.08	25.01 ± 0.09	43.64 ± 0.14	48.35 ± 0.16	0.90
Pigeons	48.35 ± 0.62	16.48 ± 0.21	23.67 ± 0.30	34.08 ± 0.43	48.96 ± 0.62	0.70
Dogs	56.82 ± 0.62	26.70 ± 0.29	30.12 ± 0.32	46.99 ± 0.51	53.01 ± 0.57	0.87
Cats	62.36 ± 1.13	25.41 ± 0.46	36.95 ± 0.66	40.75 ± 0.73	59.25 ± 1.07	0.96
Mice	64.31 ± 0.33	26.72 ± 0.13	37.59 ± 0.19	41.55 ± 0.21	58.45 ± 0.29	0.71
Rats	76.23 ± 1.12	33.86 ± 0.49	42.37 ± 0.62	44.42 ± 0.64	55.58 ± 0.81	0.80

**Table 2: Electrophoretic patterns of serum proteins of healthy cows, buffaloes, camels, sheep, goats and rabbits ( relative value, %) (mean  $\pm$  S.E.).**

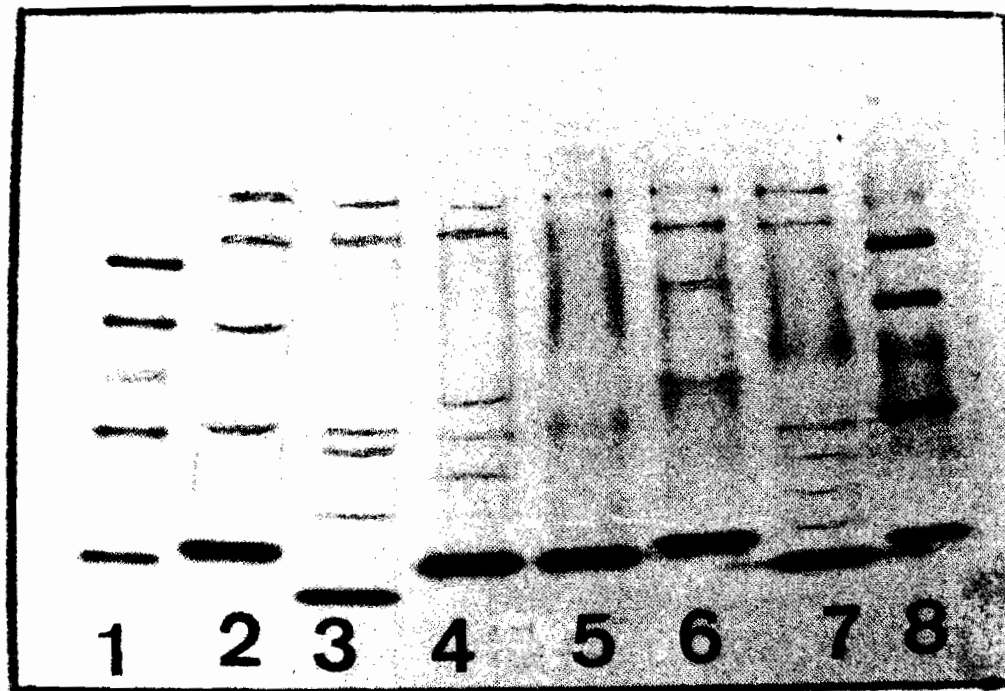
Protein fraction	Cows	Buffaloes	Camels	Sheep	Goats	Rabbits	
Albumin	45.93 $\pm$ 0.72	49.75 $\pm$ 0.66	48.62 $\pm$ 0.22	42.82 $\pm$ 0.42	47.33 $\pm$ 0.51	46.27 $\pm$ 0.17	
Globulin	Total	54.07 $\pm$ 0.84	50.25 $\pm$ 0.67	51.38 $\pm$ 0.24	57.18 $\pm$ 0.73	52.67 $\pm$ 0.56	53.73 $\pm$ 0.19
	$\alpha$	14.93 $\pm$ 0.85	12.76 $\pm$ 0.17	-----	-----	9.48 $\pm$ 0.10	-----
	$\alpha_1$	----- ---	-----	5.31 $\pm$ 0.02	7.11 $\pm$ 0.09	-----	6.90 $\pm$ 0.02
	$\alpha_2$	----- ---	-----	7.53 $\pm$ 0.03	8.89 $\pm$ 0.11	-----	5.13 $\pm$ 0.01
	$\beta$	17.72 $\pm$ 0.27	15.95 $\pm$ 0.21	-----	-----	-----	-----
	$\beta_1$	-----	-----	6.69 $\pm$ 0.03	10.25 $\pm$ 0.13	11.96 $\pm$ 0.12	8.75 $\pm$ 0.03
	$\beta_2$	-----	-----	7.82 $\pm$ 0.03	11.13 $\pm$ 0.14	8.56 $\pm$ 0.09	6.08 $\pm$ 0.02
	$\gamma$	21.42 $\pm$ 0.33	21.54 $\pm$ 0.28	24.03 $\pm$ 0.11	-----	22.67 $\pm$ 0.24	26.87 $\pm$ 0.09
	$\gamma_1$	-----	-----	14.72 $\pm$ 0.18	-----	-----	
	$\gamma_2$	-----	-----	5.08 $\pm$ 0.06	-----	-----	
A/G ratio	0.85	0.99	0.95	0.75	0.90	0.86	

**Table 3: Electrophoretic patterns of serum proteins of healthy horses, donkeys, mules, chickens, turkeys and pigeons ( relative value, %) (mean  $\pm$  S.E.).**

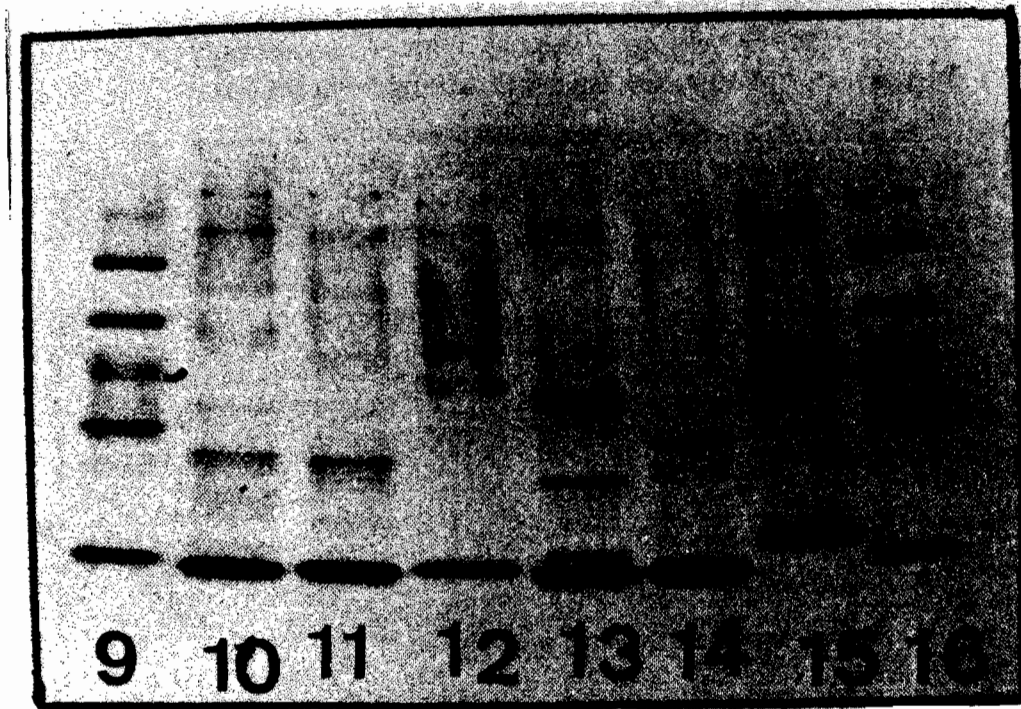
Protein fraction		Horses	Donkeys	Mules	Chicken	Turkeys	Pigeons
Pre-albumin		-----	-----	-----	10.16 $\pm$ 0.03	8.01 $\pm$ 0.02	16.96 $\pm$ 0.21
Albumin		45.82 $\pm$ 0.50	48.40 $\pm$ 0.34	46.68 $\pm$ 0.51	40.01 $\pm$ 0.12	43.64 $\pm$ 0.14	34.08 $\pm$ 0.43
Globulin	Total	54.18 $\pm$ 0.60	51.60 $\pm$ 0.36	53.32 $\pm$ 0.58	49.83 $\pm$ 0.15	48.35 $\pm$ 0.16	48.96 $\pm$ 0.62
	$\alpha_1$	3.96 $\pm$ 0.04	2.42 $\pm$ 0.01	3.59 $\pm$ 0.03	6.89 $\pm$ 0.02	7.12 $\pm$ 0.02	5.83 $\pm$ 0.07
	$\alpha_2$	9.99 $\pm$ 0.11	10.17 $\pm$ 0.07	10.45 $\pm$ 0.11	8.22 $\pm$ 0.02	9.03 $\pm$ 0.03	6.52 $\pm$ 0.08
	$\beta_1$	13.85 $\pm$ 0.15	11.60 $\pm$ 0.08	14.40 $\pm$ 0.15	6.43 $\pm$ 0.02	8.27 $\pm$ 0.02	7.10 $\pm$ 0.09
	$\beta_2$	8.59 $\pm$ 0.09	8.50 $\pm$ 0.06	6.25 $\pm$ 0.06	9.19 $\pm$ 0.02	10.21 $\pm$ 0.03	12.14 $\pm$ 0.15
	$\gamma$	17.79 $\pm$ 0.19	18.91 $\pm$ 0.13	18.63 $\pm$ 0.20	19.10 $\pm$ 0.06	13.72 $\pm$ 0.04	17.37 $\pm$ 0.22
A/G ratio		0.85	0.94	0.88	0.80	0.90	0.70

**Table 4: Electrophoretic patterns of serum proteins of healthy dogs, cats, mice and rats ( relative value, %) (mean  $\pm$  S.E.).**

Protein fraction		Dogs	Cats	Mice	Rats
Albumin		46.99 $\pm$ 0.51	40.75 $\pm$ 0.73	41.55 $\pm$ 0.21	44.42 $\pm$ 0.64
Globulin	Total	53.01 $\pm$ 0.57	59.25 $\pm$ 1.07	58.45 $\pm$ 0.29	55.58 $\pm$ 0.81
	$\alpha_1$	4.51 $\pm$ 0.05	6.31 $\pm$ 0.11	10.45 $\pm$ 0.05	14.08 $\pm$ 0.20
	$\alpha_2$	7.97 $\pm$ 0.08	7.46 $\pm$ 0.13	15.60 $\pm$ 0.07	10.51 $\pm$ 0.15
	$\beta$	-----	-----	18.58 $\pm$ 0.09	14.39 $\pm$ 0.21
	$\beta_1$	6.46 $\pm$ 0.07	8.60 $\pm$ 0.15	-----	-----
	$\beta_2$	11.12 $\pm$ 0.11	10.61 $\pm$ 0.19	-----	-----
	$\gamma$	-----	-----	13.82 $\pm$ 0.07	16.60 $\pm$ 0.24
	$\gamma_1$	13.27 $\pm$ 0.14	11.47 $\pm$ 0.20	-----	-----
$\gamma_2$	9.68 $\pm$ 0.11	14.80 $\pm$ 0.26	-----	-----	
A/G ratio		0.87	0.69	0.71	0.80



**Fig. 1:** Electrophoretic patterns of serum proteins of some healthy animals. 1- donkey, 2- mule, 3- cat, 4- horse, 5- cow, 6- buffalo, 7- dog, 8- camel.



**Fig. 2:** Electrophoretic patterns of serum proteins of some healthy animals. 9- pigeon, 10- goat, 11- sheep, 12- chicken, 13- albino mouse, 14- rabbit, 15- albino rat, 16- turkey.



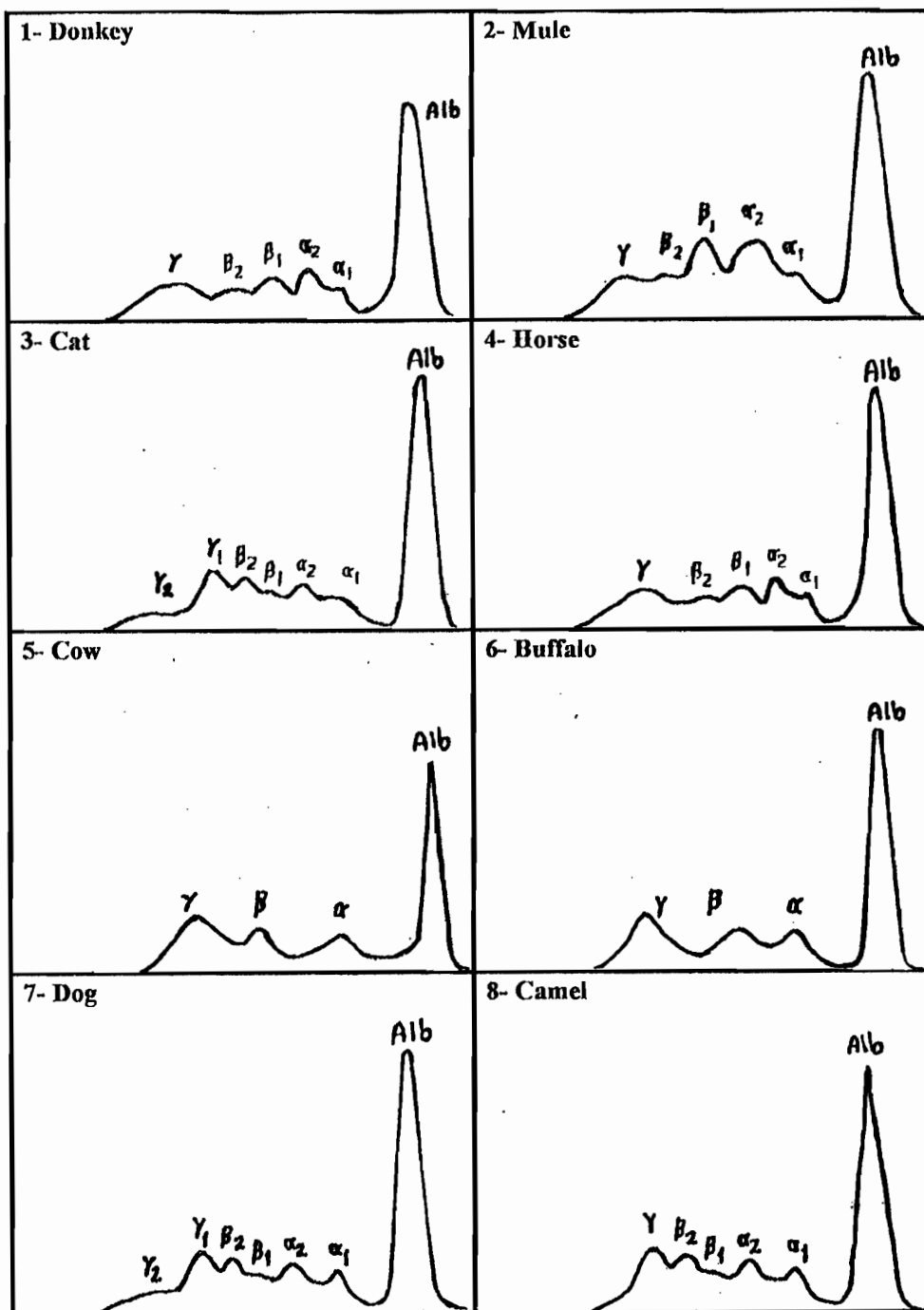


Fig. 3: Electrophoretograms of serum proteins of some healthy animals. Alb (albumin),  $\alpha$  (alpha-globulin),  $\alpha_1$  (alpha<sub>1</sub>-globulin),  $\alpha_2$  (alpha<sub>2</sub>-globulin),  $\beta$  (beta-globulin),  $\beta_1$  (beta<sub>1</sub>-globulin),  $\beta_2$  (beta<sub>2</sub>-globulin),  $\gamma$  (gamma-globulin),  $\gamma_1$  (gamma<sub>1</sub>-globulin),  $\gamma_2$  (gamma<sub>2</sub>-globulin).

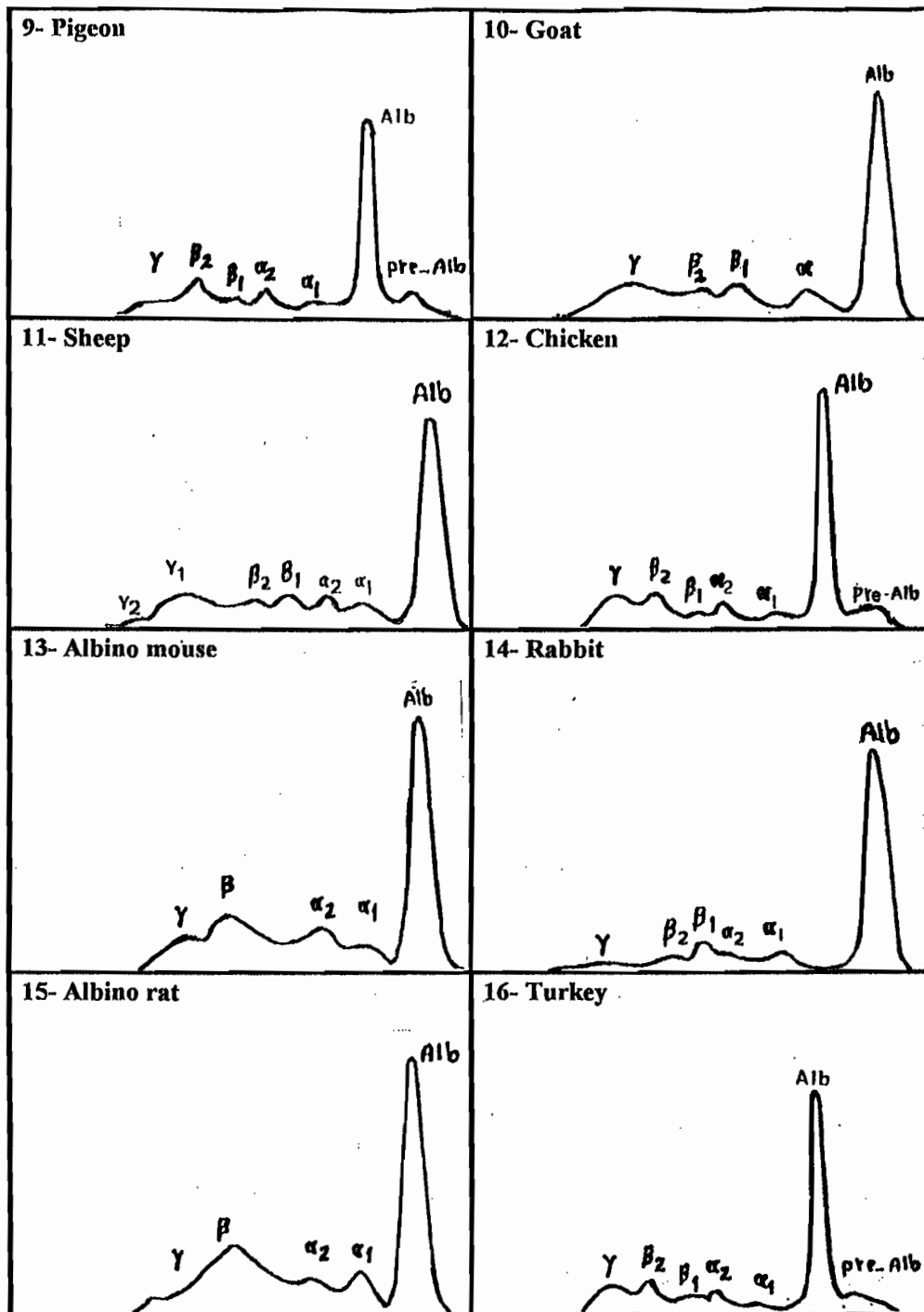


Fig. 4: Electrophoretograms of serum proteins of some healthy animals. Pre-Alb (Pre-albumin), Alb (albumin),  $\alpha$  (alpha-globulin),  $\alpha_1$  (alpha 1-globulin),  $\alpha_2$  (alpha 2-globulin),  $\beta$  (beta-globulin),  $\beta_1$  (beta 1-globulin),  $\beta_2$  (beta 2-globulin),  $\gamma$  (gamma-globulin),  $\gamma_1$  (gamma 1-globulin),  $\gamma_2$  (gamma 2-globulin).