Disseminated Mycoses in Cattle. A Study on Nine Autopsy Cases

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ABSTRACT. Nine cases affected with disseminated mucormycosis (1.3% of all autopsy cases and 20.0% of systemic mycosis) were found among bovine systemic mycosis examined from 1975 to 1985. The disseminated lesions were found in the lungs (3 cattle), heart (2 cattle), liver (2 cattle), spleen (1 beef cattle), kidneys (1 cattle), central nervous system (1 cattle) and lymph node (1 cattle). Histological examination revealed granulomatous lesions, necrotic foci including infarcts, and thromboangiitis with the hyphae of a member of the Zygomycetes and neutrophil reaction. Granulomatous lesions with asteroid bodies were found in the liver. Metastatic foci were established from the primary lesions found in the alimentary organ (4 from the forestomach or abomasum and 1 from the tongue). One case resulted from uterine mucormycosis, and no primary lesion was found in the other 3 cattle. Complicated infection with respiratory aspergillosis occurred in 4 cases with alimentary mucormycosis. All of the 9 cattle had predisposing disorders. Six cattle had been manifested with prolonged debilitating conditions. Anemia was present in 4, leukopenia in 2 and lymphopenia in 1 cattle.—**KEY WORDS:** aspergillosis, bovine disseminated mycosis, complicated infection, mucormycosis.

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Mycosis is divided into superficial (dermatomycosis) and deep-seated or systemic mycosis (SM) [3, 17, 23, 24]. Most systemic mycoses are known to be opportunistic infections [3, 23, 27].

The wide use of antibiotics, steroid and chemotherapeutic agents has led to a significant increase in the occurrence of SM, especially in multi-organ involvement due to hematogenous dissemination of fungal organisms in man [1, 21]. At present, disseminated mycosis (DMY) is diagnosed when the lesions are regarded to be depending on a hematogenous spread [1].

Although disseminated aspergillosis (DA) [8, 9, 15] and disseminated mucormycosis (DM) [6, 8, 11, 12, 22, 26, 29] have been reported in cattle, the rate of the incidence is not yet known well. This report deals with pathological examination of DMY in adult cattle.

The term “mucormycosis” used here designates infection caused by hyphae showing the morphological characteristics of Zygomycetes and having suppurative cellular reaction without eosinophils in the tissue [4, 23].

MATERIALS AND METHODS

Autopsies were done on 692 cattle (mostly Hol-

stein-Friesian cows) older than 6 months, at the Department of Veterinary Pathology, Rakuno Gakuen University, from April, 1975 through March, 1985. Forty five of them were affected with SM, out of which 9 cattle showed DMY.

At autopsy, tissues were collected from the whole body, fixed in 10% neutral formalin solution and processed routinely for paraffin embedding. Sections were stained with hematoxylin and eosin (HE). Selected sections were stained with periodic acid-Schiff (PAS) reaction and Gomori's methenamine silver (GMS).

RESULTS

Forty-five (6.5%) of the 692 cattle autopsied were diagnosed as SM. Nine cattle (20% of diagnosed SM and 1.3% of all cattle autopsied) were diagnosed as DMY. A summary of the findings of these 9 cases is presented in Table 1. Five cases (Nos. 1, 3, 6, 8 and 9) had complicated infection with Zygomycetes and *Aspergillus* in different organs. Mixed infections of Zygomycetes and *Aspergillus* were seen within a lesion of the forestomach (No. 9) and lungs (No. 6). The other 4 cattle (Nos. 2, 4, 5 and 7) had DM.

Clinical history: Table 1 shows concurrent clinical findings of the cattle affected with DMY. No. 1 showed anorexia, lethargy and bloat. These signs were accompanied by diarrhea and atony of the rumen from the 9th day. Marked dehydration and

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Table 1. Summary of findings in 9 cases with disseminated mycosis

Cattle No.	Age ^{a)} (years)	Concurrent clinical and pathological diagnosis	Organs involved ^{b)}									Treatment with antibiotics ^{c)} (duration, days)	Outcome and course of illness (days)		
			Liver	Spleen	Kidney	Heart	Lung	CNS	Lymph node	Tongue	F. Stomach			Abomasum	Uterus
1	9 (months)	Rumen atony, diarrhea, dehydration, chronic fibrous pericarditis, traumatic peritonitis		M*			A				M		+	(6)	Died 24
2	1	Hemolytic anemia, thrombocytopenia, chronic endocarditis, focal necrosis of the liver, interstitial nephritis, abomasal ulcer, necrotic endometritis						M*					+	(8)	Died 65
3	3	Rumen atony, diarrhea, anemia, leukopenia, necrotic placentitis, necrotic purulent bronchitis					A		M*	M			+	(6)	Died 13
4	4	Rumen atony, anemia, lymphosarcoma					M*				M	M	—		Died 30
5	6	Pregnancy, rumen atony, downer, leukopenia, hemorrhagic diarrhea, necrotic mastitis	M*								M		+	(9)	Died 10
6	9	Postparturient prolapse of uterus, downer, rumen atony, necrotic mastitis, myocardial degeneration	M*		M*		M* A				A	M	+	(18)	Killed 25
7	10	Chronic traumatic pericarditis, anemia, lymphopenia, cachexia, bovine papular stomatitis, liver abscess, mucosal erosion of the tongue and esophagus						M*					+	(?)	Died 24
8	11	Chronic mastitis, suppurative necrotic pneumonia, amyloidosis, catarrhal endometritis, hypoalbuminemia, suppurative necrotic galactophoritis					M* A						+	(11)	Killed 17
9	Adult	Difficult parturition, downer, rumen atony, chronic endocarditis, necrotic mastitis, necrotic endometritis, renal infarction, interstitial nephritis, necrobacillosis in the forestomach					M* A				M	M A	+	(8)	Killed 20

Note: a) All cattle are Holstein-Friesian females except No. 7 which is Japanese Black female.

b) M; primary lesions of mucormycosis. M*; metastatic lesions of mucormycosis.

A; primary lesions of aspergillosis. CNS; central nervous system. F. Stomach; forestomach.

c) -; not done. +; treated.

leukocytosis (35,000/ μ l) with neutrophilia were recorded.

No. 2 showed anorexia and high body temperature (40.7°C) on the first day of illness. Two months later, blood examination revealed marked anemia (Ht; 23%) with immature erythrocytes, lymphocytosis (38,000/ μ l) with neutrophilia, icterus (icterus

index; 42), thrombocytopenia (19×10^3 / μ l) and prolonged coagulation time. Urinalysis disclosed positive occult blood and proteinuria.

No. 3 showed sudden anorexia, rumen atony, diarrhea and symptoms of pneumonia, which was followed by abortion 4 days later. Anemia (Ht; 19%) and leukopenia (3,600/ μ l) were observed.

No. 4 showed anorexia a month after the first signs of illness. There were enlargement of superficial lymph nodes and subcutaneous edema. Blood examination revealed anemia (Ht; 12%), slight increase of white blood cell count ($10,300/\mu\text{l}$), lymphocytosis ($9,200/\mu\text{l}$) and appearance of atypical lymphocytes ($1,300/\mu\text{l}$).

No. 5 suffered from acute mastitis and was recumbent. Leukopenia ($3,500/\mu\text{l}$) after antibiotic therapy and hemorrhagic diarrhea the day before her death were seen.

No. 6 had suffered from postparturient prolapse of the uterus and necrotic mastitis, and became a downer. Blood examination revealed leukocytosis ($17,700/\mu\text{l}$) with left shift of neutrophils ($14,800/\mu\text{l}$).

No. 7 was diagnosed as traumatic pericarditis on 11th day post-parturition. Anemia (Ht; 12%), leukocytosis ($32,000/\mu\text{l}$) with left shift neutrophilia and lymphopenia ($800/\mu\text{l}$) were seen from the 16th to 32nd day post-parturition.

No. 8 suffered from mastitis in the late stage of her pregnancy. Pneumonia was observed one week after the parturition. Blood examination revealed leukocytosis ($19,500/\mu\text{l}$) with left shift neutrophilia ($15,500/\mu\text{l}$), hypoalbuminemia (1.9 g/dl) and hyperglobulinemia (5.7 g/dl).

No. 9 showed anorexia, emaciation, rumen atony and slight anemia.

Pathological findings: Major pathological diagnoses are shown in Table 1.

No. 1: Macroscopically, there were adhesive fibrinous peritonitis, pseudomembranous rumenitis, and purulent bronchopneumonia. Histopathologically, necrotic and fibrinous capsulitis with hyphae and neutrophil infiltration were found in the spleen. Anemic infarcts with emboli of hyphae which were nonseptate and bulbous showing the characteristics of *Zygomycetes* (Fig. 1) were seen in the spleen.

Granulomatous lesions containing asteroid bodies and irregular hyphal proliferation were found in the areas from the lamina propria to the submucosa in the rumen and omasum.

Chronic pulmonary aspergillosis was found. There were encapsulated abscesses containing radially proliferated hyphae, granulomas with asteroid body and cavities replaced by fungal ball in the lesion of pulmonary aspergillosis.

No. 2: Grossly, nodules approximately 5 mm in diameter were scattered in the lungs. The center of the nodules was yellowish and surrounded by a reddish marginal zone.

Fig. 1. Necrotic and fibrinous capsulitis with hyphal proliferation in the splenic pulp. The hyphae are bulbous and irregularly branched showing characteristic morphology of *Zygomycetes*. GMS and HE. $\times 180$.

Histopathologically, focal necrosis with fungal thromboangiitis, neutrophil infiltration and abscesses were observed in the lungs. Hyphae showed the characteristics of *Zygomycetes*.

No. 3: Autopsy revealed enlargement of the left superficial cervical lymph node ($10 \times 8 \times 7$ cm) with central necrosis. Reddish black nodules approximately 5 cm in diameter and hard whitish yellow abscesses approximately 5 mm in diameter were scattered all over the lungs.

Microscopically, necrotic hemorrhagic lymphadenitis with fungal emboli in the capsule, proliferation of hyphae in the parenchyma, necrotic arteritis with hyphal invasion and follicular depletion were seen in the superficial cervical lymph node. An ulcer with granulomatous lesion containing asteroid bodies was found in the tongue. These lesions were caused by *Zygomycetes*. In addition, hemorrhagic necrotic fibrinous bronchopneumonia due to *Aspergillus* sp. was seen.

No. 4: At autopsy, hard and yellowish brown, focal necrotic lesions (1.0–2.5 cm in diameter) with hemorrhages were seen in the lungs. Focal hemorrhages and yellowish necrotic lesions (2.5×2.5 cm) were seen in the mucosa of the forestomach. Hemorrhagic ulcer about 3 cm in diameter was found in the abomasal mucosa.

Perivascular focal necrotic lesions with fungal thromboangiitis and hemorrhages were scattered in the lungs. Haphazardly branching, nonseptate

Fig. 2. Fungal thromboangiitis in the lung. Nonseptate hyphae characterized by haphazard branching proliferate in the thrombi and vascular wall. There are many lymphocytic neoplastic cells around the vessels. GMS and HE. $\times 180$.

Fig. 3. Granulomatous lesion containing asteroid body surrounded by neutrophils and epithelioid cells in the liver. HE. $\times 360$.

hyphae, 4–8 μm in width, proliferated in the thrombi and necrotic vascular wall (Fig. 2).

Focal hemorrhagic necroses were found in the mucosa and extended to the submucosal or muscular layer of the rumen and omasum. Fungal thrombi were scattered in the lesions. Mucosal ulcer accompanied with lymphoid neoplastic cell proliferation was observed in the abomasum. Hyphae with infiltration of neutrophils and fungal emboli were detected around the lesion in the abomasum.

No. 5: Autopsy revealed several grayish-white nodules (0.5–1.0 cm in diameter) in the liver, penetrated ulcer of the omasal leaves, and hemorrhages in the mucosa of the rumen.

Granulomatous lesions containing asteroid bodies, and hyphal emboli were seen in the liver (Fig. 3). In the rumen and omasum, granulomatous

Fig. 4. Mixed infection with hyphae of *Aspergillus* and *Zygomycetes*. Hyphae of *Aspergillus*, strongly positive for GMS stain, are seen in the alveolar and bronchiolar lumens. Hyphae of *Zygomycetes* are present in thrombi and invade the surrounding tissue. GMS and HE. $\times 180$.

lesions with asteroid bodies were found from the mucosa to the serosa.

No. 6: Autopsy revealed focal necroses (5–8 mm in diameter) in the liver, purulent nephritis consisting of whitish nodules (1–5 mm in diameter), focal necroses in the lungs with thrombi and ulcers in the rumen and abomasum.

Microscopically, focal necroses and granulomatous lesions with hyphae were seen in the liver. Anemic infarcts with hyphal emboli were found in the kidneys with granulomatous lesions around the necrotic foci. Desquamation of the endometrium and focal necrosis with hyphal thromboangiitis, neutrophil infiltration and granulomatous lesions containing asteroid body were found in the endometrium to myometrium. Hyphae showed the characteristics of *Zygomycetes*.

There were encapsulated abscesses with radially proliferated hyphae, cavitation and focal pseudomembranous necrosis in the bronchiolar mucosa of the lungs. Septate hyphae showed dichotomous Y-shaped branching, averaging 4 μm in width showing characteristics of *Aspergillus* sp. Additionally, hyphae of a member of *Zygomycetes* proliferated in the thrombi, and periarterial necrosis and hyphal invasion to the surrounding tissues were marked (Fig. 4).

Mucosal focal necrosis, and ulcer with hyphal proliferation of *Aspergillus* sp., neutrophil infiltration and granulation tissue were found in the submucosa of the rumen.

No. 7: At autopsy, focal fibrinous thickening of an area (2.5 $\times$ 2.0 cm) was found on the meninges in the

Fig. 5. Hyphae of Zygomycetes are seen in the myocardial fibers. Cross section. GMS and HE. $\times 360$.

Fig. 6. Hyphae of Zygomycetes are present in or along myocardial fiber. Longitudinal section. GMS and HE. $\times 360$.

dorsal portion of the left occipital lobe. The details of the lesion of the central nervous system have been described elsewhere [6], in which it was diagnosed as thrombo-embolic meningo-encephalitis with cortical necrosis and medullary demyelination due to infection of Mucorales.

No. 8: Autopsy revealed 4 demarcated infarcts (5×3 cm) in the both ventricular walls of the heart. Many whitish-yellow nodules (3–5 mm in diameter) were scattered all over the lungs.

Large infarcts were found in the endocardium to myocardium with hyphal thromboangiitis and marked hemorrhages. Marked infiltration of neutrophils and mononuclear cells accompanied by proliferation of histiocytic cells was seen in the lesions. The irregularly proliferated hyphae in the lesion were identified as a member of the Zygomycetes.

The hyphae tended to proliferate in or along the myocardial fibers (Figs. 5 and 6).

Chronic pulmonary aspergillosis which showed fibrinous pneumonia as well as necrotic bronchitis or bronchiolitis was found and the granulation tissue contained radially proliferated hyphae.

No. 9: Autopsy revealed verrucous endocarditis in the bicuspid valve, and hemorrhagic necrotic foci (1–3 cm in diameter) in the myocardium and lungs. Focal pseudomembranous mucosal lesions were scattered in the bronchi, and ulcers (0.3–3.0 cm in diameter) were seen in the rumen mucosa. Penetration of the omasum leaves and mucosal ulcers of the abomasum were found sporadically.

Histological findings in the heart were similar to those of No. 8.

Necrotic foci spreading from the mucosa to the muscular layer, with infiltration of neutrophils and fungal thrombi were observed in the rumen and omasum. Hyphae of *Aspergillus* sp. proliferated in the necrotic lesions of the rumen. Histological diagnosis of the rumen and omasum was a complication of necrobacillosis, mucormycosis and aspergillosis. Focal necrosis from the mucosa to the submucosa was found in the abomasum with hyphal proliferation and thrombosis. In the lungs, there were bronchitis and bronchiolitis due to infection with *Aspergillus*.

DISCUSSION

The terms “mucormycosis” and “zygomycosis” cause some confusions when they are used in the histopathological diagnosis without identification of the aetiologic agents [4]. Chandler *et al.* [4] state that zygomycosis is a polymorphic disease of multiple aetiology and the umbrella term “zygomycosis” adequately and clearly covers all zygomycete infections regardless of the classification of the aetiologic agents. Rippon [23] uses the term “mucormycosis” for the infection caused by various species of the order Mucorales and states that the organisms are members of the order Mucorales of Zygomycota, quite distinct taxonomically and in the type of disease evoked from other pathogenic zygomycetous fungi. Under the infection by species of the Mucorales, there are more commonly suppurative or pyogenic cellular reaction and accumulation of neutrophils in the tissue. Eosinophils are not seen as frequently as in infection of other pathogenic zygomycetous fungi [4, 23]. In the present paper,

the lesions caused by the hyphae characterized Zygomycetes were diagnosed as mucormycosis according to the characterized cellular reaction of neutrophils to the hyphae.

The alimentary tract is considered to be the most important portal of entry of the fungus for DMY in cattle [9, 11, 12, 15, 22, 26, 29, 30] and the liver is commonly affected [9, 11, 12, 15, 22, 26, 28]. In the present study, 5 cattle were infected through the alimentary organ and 1 cattle from the uterus whereas the portal of entry for 3 cattle was unknown. Thus, alimentary mucormycosis could be a significant primary lesion of DMY.

Lowered resistance to infection, presence of several debilitating diseases and antibiotics or corticosteroid therapy [16, 21, 25] have been known as predisposing factors for SM. All cattle in the present study suffered from debilitating chronic diseases as chronic mastitis (4 cattle), endometritis (3 cattle), endocarditis (2 cattle), pericarditis (2 cattle), chronic pneumonia (2 cattle) and malignant lymphosarcoma (1 cattle). Hematological findings in the 9 cattle showed anemia (4 cattle), leukopenia (2 cattle), lymphopenia (1 cattle) and thrombocytopenia (1 cattle) as underlying conditions. Abe *et al.* [1] stated that hematologic disorders were the most frequent underlying disorders in human disseminated fungal infection. These factors tend to decrease resistance to infection.

In the present cases, 7 of 9 cattle examined had received antibiotics. The dose of the antibiotics was not exceeded, and treatment with antibiotics is not a very important predisposing factor.

In this study, DMY was found in 9 cattle (20.0%) in the 45 SM of our autopsy cases. Fungal granulomatous lesions were reported in the bovine mesenteric lymph nodes [2, 10, 20], and pulmonary and mediastinal lymph nodes [10, 13, 14, 18, 19] in the samples collected at abattoirs. Many subclinical SM might be present in apparently healthy animals. There might be many opportunities that advance SM for DMY.

The lesions of DMY are characterized by well demarcated necrosis including infarcts and thromboangiitis. These findings indicate hematogenous metastasis.

Cardial mucormycosis has been reported [7, 29], though no morphological feature was described. Cardiac lesions were found in 2 cattle in the present study. Elongated hyphae proliferated in and along the myocardial fiber. Compared with the dichoto-

mous branching of *Aspergillus* in myocardium [5], the feature of hyphal proliferation in and along the myocardial fiber seems to be the characteristics of Mucorales.

Granulomatous lesions have been reported in the mesenteric [2, 10, 20], and both bronchial and mediastinal [10, 13, 18, 19] lymph nodes. The findings seemed to indicate host resistance to mycotic infection in the local region. Granulomatous lesions were found in the liver, uterus, and tongue in the present study. This suggests that appearance of the lesions seems to depend on the course of the disease and resistance of the tissues to infection. The granulomatous lesion might develop during subclinical infection in healthy cattle.

The fungal lesions in the forestomach of cattle 9 might be preceded by association of necrobacillosis.

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REFERENCES

1. Abe, F., Tateyama, M., Shibuya, H., Azumi, N., and Ommura, Y. 1984. Disseminated fungal infection. A review of 20 autopsy cases. *Acta Pathol. Jpn.* 34: 1201-1208.
2. Angus, K. W., Gilmour, N. J. L., and Dawson, C. O. 1973. Alimentary mycotic lesions in cattle: A histological and cultural study. *J. Med. Microbiol.* 6: 207-213.
3. Biberstein, E. L. 1981. The systemic mycoses. pp. 753-763. In: *Current Veterinary Therapy. Food Animal Practice* (Howard, J. L. ed.), W. B. Saunders Company, Philadelphia.
4. Chandler, F. W., Kaplan, W., and Ajello, L. 1980. Zygomycosis. pp. 122-127, 294-301. In: *A Colour Atlas and Textbook of the Histopathology of Mycotic Diseases*, Wolfe Medical Publication Ltd., London.
5. Chihaya, Y., Matsukawa, K., Furusawa, Y., Hatta, Y., Okada, H., and Arisawa, K. 1988. Disseminated aspergillosis with lesions in the central nervous system in a calf. *Jpn. J. Vet. Sci.* 50: 131-137.
6. Chihaya, Y., Matsukawa, K., and Okada, H. 1986. A case of bovine cerebral mucormycosis. *Jpn. J. Vet. Sci.* 48: 1271-1274.
7. Cordes, D. O., Royal, W. A., and Shortridge, E. H. 1967. Systemic mycosis in neonatal calves. *N. Z. Vet. J.* 15: 143-149.
8. Cordes, D. O. and Shortridge, E. H. 1968. Systemic phycomycosis and aspergillosis of cattle. *N. Z. Vet. J.* 16: 65-80.
9. Cousin, D. A. H., Maloney, S. C., Bannatyne, C. C., and Angus, K. W. 1973. Fatal disseminated mycotic infection in a yearling bullock. *Vet. Rec.* 93: 312-313.
10. Davis, C. L., Anderson, W. A., and McCrory, B. R. 1955. Mucormycosis in food-producing animals. A report of twelve cases. *J. Am. Vet. Med. Assoc.* 126: 261-267.

11. De Lahunta, A., Van Kruiningen, H., Cummings, J., and Kallfelz, F. 1967. Clinical pathological conference on mycotic rumenitis (mucormycosis) and postpartum metritis. *Cornell Vet.* 57: 308–322.
12. Donnelly, W. J. C. 1967. Systemic bovine phycomycosis: A report of two cases. *Irish Vet. J.* 21: 82–87.
13. Gill, B. S. and Singh, B. 1976. Phycomycotic pneumonia in buffalose—a note. *Zentralbl. Veterinaermed., B* 23: 782–784.
14. Gleiser, C. A. 1953. Mucormycosis in animals. A report of 3 cases. *J. Am. Vet. Med. Assoc.* 123: 441–445.
15. Gortsevskii, S. A. 1960. Pathogenesis and pathology of fungal diseases in cows. *Veterinariya* (Moscow), No. 9: 71–72 (*Vet. Bull.* 31: 62, 1961).
16. Khoo, T. K., Sugai, K., and Leong, T. K. 1966. Disseminated aspergillosis. Case report and review of the world literature. *Am. J. Clin. Pathol.* 45: 697–703.
17. Maddy, K. T. 1967. Epidemiology and ecology of deep mycoses of man and animals. *Arch. Dermatol.* 96: 409–417.
18. Marcato, P. S., Benazzi, C., and Albrizio, M. 1981. Researches on bovine respiratory aspergillosis. *Atti Soc. Ital. Sci. Vet.* 35: 620–621.
19. Marcato, P. S., Benazzi, C., Morganti, L., Tampieri, P., and Albrizio, M. 1983. Mycotic granulomas in bronchial lymph nodes in cattle. *Clin. Vet.* 106: 90–96.
20. Pallaske, G. 1967. Mykose beim Rind im Bereiche des Verdauungsapparates (zugleich ein Beitrag zur Differentialdiagnose der Tuberkulose). *Dtsch. Tieraerztl. Wochenschr.* 74: 27–33.
21. Pedraza, M. A. 1969. Mycotic infections at autopsy. A comparative study in two university hospitals. *Am. J. Clin. Pathol.* 51: 470–476.
22. Pohlenz, J., Ehrensperger, F., und Breer, C. 1973. Spontane Todesfälle infolge Mukormykose des Vormagens beim Rind. *Schweiz. Arch. Tierheilkd.* 115: 161–168.
23. Rippon, J. W. 1982. Mucormycosis. pp. 615–640. Aspergillosis. pp. 565–594. In: *Medical Mycology. The Pathogenic Fungi and The Pathogenic Actinomycetes*, 2nd ed. W. B. Saunders, Philadelphia.
24. Saunders, L. Z. 1948. Systemic fungous infections in animals: A review. *Cornell Vet.* 38: 213–238.
25. Scaravilli, F. 1984. Parasitic and fungal infections of the nervous system. Infections by fungi. pp. 324–337. In: *Greenfield's Neuropathology*, 4th ed. (Adams, J. H., Corsellis J. A. N., and Duchen, L. W. eds.), Edward Arnold Pub., London.
26. Spratling, F. R., Sparrow, D. S. H., and Nielsen, S. W. 1968. Mycotic ruminitis in a cow. *Vet. Rec.* 82: 282–284.
27. Symmers, W. St. C. 1962. Histopathologic aspects of the pathogenesis of some opportunistic fungal infections, as exemplified in the pathology of aspergillosis and the phycomycetoses. *Lab. Invest.* 11: 1073–1090.
28. Thomson, R. G. 1967. Rumenitis in cattle. *Can. Vet. J.* 8: 189–192.
29. Watanabe, K., Tabuchi, K., Hara, M., Kiuchi, A., Sawaya, H., Shimura, S., Nomura, T., Kobayashi, N., Itoh, K., Shinoda, M., Miyashita, I., Nomura, Y., Tsuchiya, T., Saito, Y., and Hoshino, H. 1979. Mucormycosis due to *Rhizopus rhizopodiformis* in animals: A report of 3 cases. *Bull. Azabu Vet. Coll.* 4: 25–32.
30. Whiteman, C. E., Benjamin, M. M., Ball, L., and Hill, M. W. M. 1972. Bovine aspergillosis produced by the inoculation of conidiospores of *Aspergillus fumigatus* into a mesenteric or jugular vein. *Vet. Pathol.* 9: 408–425.