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The pathogen *Hafnia alvei* in veterinary medicine: a review

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Hafnia alvei is a Gram negative bacterium that belongs to the family *Enterobacteriaceae*. It is part of the intestinal flora of humans and animals, moreover it has been described from natural environments and foodstuffs. In human medicine is considered an opportunistic bacterium that causes different infections associated to underlying illnesses or predisposing factors as immunocompromised patients. The knowledge and literature about this bacterium in veterinary medicine is scarce, highlighting its importance in gastropods and bees, and it has also been described in poultry, mares, fish and ruminants producing various clinicopathologic signs.

Keywords: *Hafnia alvei*; Enterobacteria; veterinary medicine; intestinal flora; pathogen

1. Introduction

Hafnia alvei is a Gram negative rod-shaped bacterium of approximately 1 µm in diameter and 2–5 µm in length that belongs to the family *Enterobacteriaceae*. D-glucose and other carbohydrates are catabolised producing acid, with or without gas production. Oxidase negative, catalase positive and indole and Simmons citrate negative, the majority of strains are methyl red and Voges–Proskauer (VP) positive (Sakazaki 1984). *H. alvei* is lysine and ornithine decarboxylase positive, arginine dihydrolase negative, H_2S and urease negative and KCN positive. *H. alvei* reduces nitrates, ferments L-arabinose, glycerol, maltose, D-mannitol, D-mannose, L-rhamnose, trehalose and D-xylose (Sakazaki 1984). The identification of *H. alvei*, sometimes is confused with *Salmonella* H_2S negative because of *H. alvei* colonies in cultures may resemble those of *Salmonella* on routine isolation media, and also are often agglutinated by *Salmonella O* antisera (Eveland & Faber 1953; Harada et al. 1957), but *Salmonella* is VP negative whereas the great majority of *H. alvei* strains are VP positive at 22°C (Sakazaki & Tamura 1992). Most *H. alvei* strains are motile by peritrichous flagella, but its expression is influenced by temperature (Padilla et al. 2009). *H. alvei* is facultative anaerobic with optimal growth temperature at 30–37°C and is able to form biofilms according to growth phase, temperature, culture media and strain analyzed (Vivas et al. 2008; Viana et al. 2010). *H. alvei* is able to enter and persist in human and fish non-phagocytic cells, highlighting the possibility that this pathogen may exploit these types of cells to spread in vivo, which may be important for the persistence and establishment of an asymptomatic carrier state (Padilla et al. 2008, 2010).

H. alvei is part of the intestinal flora of humans and it has been described from natural environments such as soil, sewage and water (Allen 1982; Allen et al. 1983; Sakazaki & Tamura 1992). The intestinal tract of animals, in particular mammals, appears to be a very common ecologic habitat for this bacterium (Janda & Abbot 2006). Thus, *H. alvei* has been isolated from reptiles (snakes and skinks), fish, invertebrates, insects and avian (Goldstein et al. 1981; Goatcher et al. 1987; Cassel-Beraud & Richard 1988; Okada & Gordon 2003). It has also been isolated from different kinds of foodstuffs such as milk (Texdorf et al. 1975), honey (Salimov 1978) and cheese (Tornajadillo et al. 1993), being responsible for the deterioration of meat packaged under a low oxygen atmosphere, minced meat, pork products and chub-packed ground beef (Borah et al. 1992; Refaie et al. 1993; Gamage et al. 1997; Lindberg et al. 1998).

2. *H. alvei* in human medicine

As pathogen, humans have generally been considered an opportunistic bacteria, and may cause infections associated to underlying illnesses or predisposing factors as immunocompromised patients (Sakazaki & Tamura 1992), causing septicaemia (Englund 1969; Ginsberg & Goldsmith 1988; Fazal et al. 1997; Liu et al. 2007), endocarditis (Gallego et al. 1999; Loulergue et al. 2007), meningitis (Mojtabaee & Siadati 1978), pneumonia (Klapholz et al. 1994; Fazal et al. 1997), abscesses

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(Agustin & Cunha 1995), urinary infections (Sakazaki & Tamura 1992; Krieg & Sneath 1994; Ramos & Dámaso 2000; Cardile et al. 2011), peritonitis (Jung et al. 2010; Yap et al. 2010), endophthalmitis (Ruiz-Moreno et al. 2001), cholecystitis (Palaniswamy et al. 2009), intestinal disorders (Harada et al. 1957; Emslie-Smith 1961; Ratnam 1991; Westblom & Milligan 1992; Reina et al. 1993; Ridell et al. 1994) and postenteritic arthritis (Newmark et al. 1994).

3. *H. alvei* in veterinary medicine

Although knowledge of *H. alvei* is over 50 years, very little is known about this bacteria as pathogen in veterinary medicine (Janda & Abbott 2006). *H. alvei* has been reported in outbreaks of disease in a variety of animal species such as cows, goats, chickens, mares, ducks, snails, fish and bees.

3.1. Poultry

In Spain (1996), *H. alvei* was isolated from laying hens displaying a reduction in egg production, loss of appetite, opisthotonus and daily mortality of 40–50 birds. At necropsy, the most significant lesions were observed in liver, which was enlarged with numerous randomly scattered whitish-yellow foci, 4–5 mm in diameter, throughout the parenchyma. A diffuse thickening of the intestinal wall with catarrhal exudate on the mucosas surface and splenomegaly were also observed. Severe multifocal necrotizing hepatitis and splenitis were the most prominent histologic lesions. Intestine showed hyperemia and diffuse catarrhal enteritis with loss of epithelial cells and heterophils infiltrating the lamina propria. In addition, six 30-week-old hens were experimentally inoculated with a dose of 3×10^8 bacteria per bird by oral and intraperitoneal route to study the pathogenicity of the organism. This trial showed similar clinicopathologic effect, opisthotonus, reduction in egg production and diarrhoea during 7 days post-inoculation. Several experimentally infected laying hens (3/6) died due to a septicaemia similar to that reportedly by *salmonella* in avian species (Real et al. 1997).

A few years later, Casagrande et al. (2004) reported in Italy a new natural outbreak of disease caused by this pathogen in pullets. Cloudy swelling and the fatty degeneration of liver associated with splenic lymphocytic depletion were the most prominent lesions. Experimental infection was carried out in laying hens and pullets by oral and intraperitoneal route. The clinical and pathological effects were similar to those observed in naturally infected subjects. Clinical signs in inoculated pullets were anorexia, depression, ruffled feathers and diarrhoea. In spite of amoxicillin administration the mortality peaked at 20.7%.

Finally, a co-infection of *H. alvei* and *Salmonella typhimurium* in ducks is reported by Simpraga et al. (2005). In affected ducks, clinical signs of the disease included reduced feed and water intake, depression, reduction in egg production and diarrhoea in a small number of animals. At necropsy, the dead ducks by the infection, showed liver dystrophy with numerous whitish-yellow foci, splenomegaly, myocardial and kidney degeneration, pancreolysis and catarrhal enteritis. The bacteria *H. alvei* and *S. typhimurium* were isolated from different organs and identified using serological agglutination method and biochemical characterization with Analytical Profile Index (API) strips. Based on the isolated bacteria susceptibility testing, enrofloxacin was administered as therapy.

3.2. Horses

In mares, *H. alvei* can produce abortions in different periods of gestation. In 1962, *H. alvei* was isolated in pure culture from the fetus and placenta, detecting a high titer of agglutinating antibodies in convalescent mare (Kume 1962). Later, Ximena and Oriele (1983) described the case of a mare that spontaneously aborted at month 8 of pregnancy. In the necropsy, the fetus had normal appearance and visual examination of liver showed only a small whitish area of approximately 5 mm in parietal area, and the examination of the placenta was completely normal. In the fetus and placenta, *H. alvei* was isolated in pure culture, and in the mare were detected agglutinating antibodies against this pathogen.

Finally, Mukherjee et al. (1986) described an abortion in a mare at 122 days of gestation. The mare had vaginal discharge for 13 days prior to abortion. The only bacteria isolated and identified from blood, amniotic fluid and fetal stomach contents was *H. alvei*, and the authors carried out an experimental infection in mice, but this strain was not lethal to mice and the necropsy revealed no apparent gross damage. The serum of the mare was tested against *H. alvei* antigen, detecting a titer of 1:80 while sera from three healthy mares used as controls had no antibody titers.

3.3. Ruminants

In merino sheep, *H. alvei* produces a retardation growth of wool with alteration of the yolk into a yellow, sticky, wax-like substance in the dermis, with hyperemia and cellular infiltration (Jansen & Hayes 1983). Sharma et al. (1991) conducted a study in a group of goats suffering from pneumonia in different degrees, obtaining that *H. alvei* represented 9.83% of total bacteria isolated from these samples. Also, *H. alvei* is an agent capable of producing chronic mastitis in cows (Binde & Hermansen 1982).

3.4. Bees

H. alvei has been frequently described in bees and is isolated and associated with disease and death-causing septicaemia (Glinski et al. 1994). Kauko and Glinski (1994) isolated *H. alvei* from the digestive tract and tissues of bees, and an experimental infection was carried out with *H. alvei* by inoculation into the chest, causing septicaemia with mortality rate of over 90%, and posterior isolating of *H. alvei* in pure culture from tissues of dead bees. Finally, Glinski et al. (1995) described a case of bee mortality where *H. alvei* was isolated from different tissues, intestines and honey from the hive, identifying this pathogen as the primary agent in septicemic infection in bees.

3.5. Fish

In aquaculture, few genera of the family *Enterobacteriaceae* are pathogens for fish, such as *Yersinia* and *Edwardsiella* (Tobback et al. 2007; Hossain et al. 2009). In fish, the first publication of *H. alvei* as pathogenic bacteria was reported by Gelev et al. (1990) associating this pathogen with epizootic hemorrhagic septicaemia in rainbow trout (*Oncorhynchus mykiss*). Years later, Teshima et al. (1992) reported kidney pathology in first-year juveniles of cherry salmon (*Oncorhynchus masou*) in Japan. Externally the fish showed a dark body surface and a swollen abdomen. Internally, kidney appears as greyish-white furuncle-like eminences, lesions very similar to those reported by *Renibacterium salmoninarum.* In this study also conducted experimental inoculation trials to reproduce the disease, showing that the disease took 3 months to develop at 15°C following intraperitoneal injection at 10^6–10^7 bacteria/fish.

Experimentally, *H. alvei* pathogenicity also has been shown, being the causal agent of mortalities in brown trout (*Salmo trutta*) after intraperitoneal injection (Rodriguez et al. 1998). In the experimental infection, similar clinical signs to those described in natural outbreaks were observed in rainbow trout and cherry salmon. Inoculated fish showed a variable susceptibility to the pathogen, with lethal dose 50 (LD_{50}) values of 10^5 (highly virulent strains) to 10^8 (non-virulent strains).

In channel, catfish (*Ictalurus punctatus*) was considered an emerging pathogen after two years many fish appeared with severe inflammation around the eyes, exophthalmia and red inflamed areas overlying the cranial fontanels, with internal lesions as ascites and red spots on liver (Goodwin & Killian 1998).

Acosta et al. (2002) established the basis for the microbiological and immunohistochemical diagnosis of *H. alvei* infection in fish. Brown trout were experimentally inoculated with *H. alvei* isolates by intraperitoneal route, and histological lesions in kidney included necrotic areas, macrovacuolar degeneration in liver and loss of the lymphatic tissue in spleen. Specific granular anti-*H. alvei* immunoperoxidase labelling was observed in the brush border of proximal segments of the tubular cells and in the base of the intestinal villi.

In marine fish, Padilla et al. (2005) analyzed experimentally the pathogenicity of *H. alvei* for gilthead seabream (*Sparus aurata*) by LD_{50} and chronic infection challenges. In this study, none of the strains used were lethal for seabream in both challenges ($LD_{50} > 10^8$ bacteria/fish); however, the bacteria remain viable in seabream tissues for up to three months without any clinical signs. In the histological study fish showed granulomatous inflammatory processes in peritoneum and kidney, and focal inflammatory lesions in liver.

3.6. Gastropods

H. alvei is considered an important pathogen in the snail culture of the genus *Helix aspersa*, affecting individuals younger than 20 days old in culture at a temperature below 15°C (Moncada et al. 2007) and isolated in 23.5% of sick snails.

4. Conclusions

In conclusion, very little information is known about *H. alvei* and the literature about this pathogen in veterinary medicine is scarce. This manuscript is an overview to better understanding of this pathogen, often regarded as an opportunistic bacteria.

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