Review Article

Gastric impaction: an important health and welfare issue of growing ostriches

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Abstract

Ostrich farming serves as a source for meat, feathers, skin, eggs, and oil. In general, ostriches are hardy birds that can resist a wide range of climatic harshness and some diseases. However, musculoskeletal and digestive complications, including the gastric impaction, remain the major cause of mortality. The gastrointestinal impaction alone is responsible for 30–46% of spontaneous deaths in growing ostriches. The literature review of 21 publications on this subject has shown that 90% of these incidents happen during first six months of life. The aetiology of this problem is mostly stress and behaviour-related gorging of feed and picking on non-feeding materials such as stone, sand, wood pieces, plastic, glass, and metallic objects. Conservative therapy or surgical approaches show good results with almost 70 to 100% recovery depending upon the clinical presentation and timely diagnosis. Overall, this literature review describes impaction in farmed ostriches, along with diagnosis, treatment, and control and preventive measures. This information will help stakeholders understand the gastrointestinal impaction in ratites to better manage this issue, reduce economic losses, and improve welfare of the birds.

Keywords: Bedding; control; prevention; digestive dysfunction; obstruction; pica; stress; treatment

INTRODUCTION

Ostrich (*Struthio camelus*) is the largest living bird which is a part of many cultures as a source of food, clothing, utensils and adornment (Munir et al., 2015). The commercial farming of this ratite began in the 1860s in South Africa, initially only for harvesting feathers every six to eight months, but became one of the major export commodities of this country at the beginning of the 20th century (Pittaway and Niekerk, 2015; Reys, 2018). Afterwards, ostrich farming spread all over the world with the objective of diversifying conventional farm animals (Bello et al., 2017). Presently, the commercialization of ostrich farming is rooted in many countries including Australia, China, Israel, Iran, Canada, Turkey, UAE, Zimbabwe, Namibia, USA, and Pakistan (Shanawany and Dingle, 1999). Moreover, these birds are part of recreational gardens and zoos in almost every country around the globe (Munir et al., 2015; Bello et al., 2017).

Although the farming of these ratites is supported by extensive research in genetics, health, and nutrition, the musculoskeletal deformities and the digestive problems remain big hurdles in welfare provision and economic achievements (Lamglait, 2018). In fact, the musculoskeletal deformities and gastric problems are interdependent, as birds with locomotion problems do not ingest food properly and their reduced movement may lead to gastric issues (Shanawany and Dingle, 1999). Furthermore, gastrointestinal (GIT) inflammation reduces nutrient absorption which weakens musculoskeletal health (Munir et al., 2015). A retrospective study by Bello et al. (2017) reported that about 46% of spontaneously dead ratites in Germany had disorders of the alimentary system, mostly with inflammatory problems. Similar findings were reported from Brazil, showing that 46% of diagnosed dysfunctions in ostriches were gastroenteric diseases. Among the GIT conditions, 83% were gastric impactions and 17% were infectious (caused by bacteria) or parasitic gastritis caused by the nematode *Libyostrongylus douglassii* (Mendonça et al., 2010). Another retrospective study spanning 40 years from a French wildlife sanctuary reported that impaction

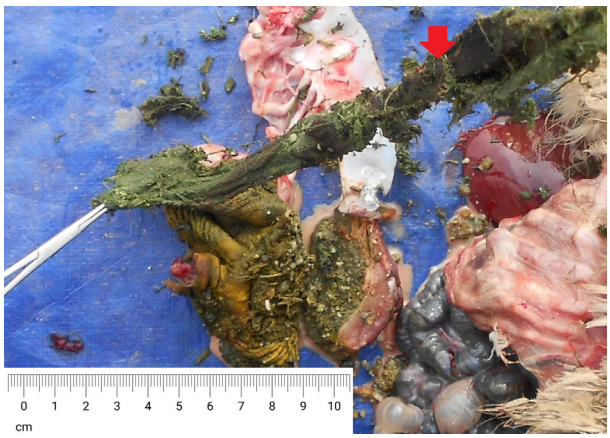

Figure 1. Gastric impaction in a three-month-old ostrich caused by ingestion of a piece of cotton bandage (left), ©Authors

Figure 2. Enteritis resulting from gizzard impaction (right), ©Authors

accounted for 30–35% of all mortalities in ostriches (Lamglait, 2018).

Thus, impaction is the most common problem in ostrich and decreasingly less likely in the rhea, emu, and cassowary, respectively (Speer, 2006). It is responsible for suffering and spontaneous deaths in ostriches, making it an important health and production issue (Mendonça et al., 2010). Understanding the underlying causes and mechanism of impaction can aid in proper diagnoses and the development of treatments and control and prevention regimes (Kumar et al., 2015).

The aim of this review is to summarise and discuss the available knowledge regarding gastric impaction in ostriches. It includes description of several aspects linked to this problem and the information will help veterinarians, farmers, and researchers to better ensure the health and welfare of ostriches and improve economic outcomes.

METHODOLOGY OF LITERATURE RESEARCH

A search was conducted on scientific research engines (11 March 2020). Different combination of words including "ostrich", "gastric", "impaction" or "constipation" or "choking" or "stasis", were searched and yielded results (in brackets) on PubMed (n = 13), Scopus (n = 22) and Web of Science (n = 13). The references and citations of these articles were also selected and added to Rayyan® for screening (Ouzzani et al., 2016). Doublings were removed, the titles were screened and the articles discussing other birds than ostriches or that were not in English were also removed. Finally, 21 articles were selected for full text review.

RESULTS AND DISCUSSION

The summary of main findings of literature is presented in Table 1. The information was used to define the gastric impaction, identify the risk factors, diagnosis, treatment, control and prevention strategies.

Gastrointestinal system and gastric impaction in ostriches

Like in all other ratites, the crop is missing in ostriches. The oesophagus opens into the proventriculus which is a large, dilated, and thin-walled organ (Stewart, 1994). Glands are restricted to a patch on the greater curvature of the proventriculus and the distal end of this organ empties into the ventriculus (gizzard) (Shanawany and Dingle, 1999). The gizzard has a thick wall and it is situated to the left of the midline at the distal border of the sternum. It normally contains small stones (grit) which help in food mixing and grinding (Speer, 2006). The internal layer of proventriculus and gizzard is called the koilin and it is formed by the protein secreted from the glands combined with entrapped sloughed cells and cellular debris (Shanawany and Dingle, 1999). The greenish to brownish colour of this tough layer is due to diet and refluxed bile (Speer, 2006) because the gall bladder is also missing in ostriches (Shanawany and Dingle, 1999). The voluminous colon of ostriches serves the function of fibre digestion and fluid absorption (Shanawany and Dingle, 1999; Aganga et al., 2003).

Gastric impaction is the accumulation of food or non-food items in the proventriculus with subsequent blockage of the opening into the gizzard causing a failure of food to move in GIT as it is evident in a case shown in Fig. 1.

The impaction can be acute or chronic depending upon whether the closure of the feed passage is partial or complete (Shanawany and Dingle, 1999). Commonly, the complete cessation of feed and water intake is noted in its acute form and birds seem to peck at feed and appear to be eating (Stewart, 1991). Thus, the quantity of faeces is greatly reduced along with pasty urine. Meanwhile, the bird's condition rapidly deteriorates and it dies within few days if treatment is not provided

Table 1. Review of literature on gastric impaction in ostriches regarding the age of bird, clinical presentation, causes, treatment and prognosis

Age (months)	N	Clinical presentation	Etiology and risk factor	Treatment	Prognosis %*	References
0.5	1	Depression, dehydration, poor-doing or chronically sick and scant feces	Chopped alfalfa and 2 to 4 cm long pieces of straw	Mineral oil feeding and then surgery	100	(Shwaluk and Finley, 1995)
1.5–2	51	Anorexia and diarrhoea and mortality in 19 birds	Transportation stress and ingestion of solid lucerne hay masses	Feed change and oral feeding of mineral oil	100	(Sato et al., 1994)
6–12 (N = 8) and 36 (N = 1)	9	Dead (N = 3) and alive (N = 6) ostriches had shown anorexia, scant defecation and whitish urine, unwillingness to rise and consume water	Stones, sand, hay stems and leaves, and even plastic and metallic objects	Birds (N = 5) were surgically operated	100	(Komnenou et al., 2003)
3–24	14	Anorexia, decreased defecation, emaciation, listlessness, separation from the flock and recumbency	Stress of new location and ingestion of stone, sand, wood pieces, glass, plastic and metallic objects	250 ml infusion of dextrose 5% + saline 0.9% and isolyte for 3 days. Amoxycillin + clavulanic acid 10 mg/kg I/M for 5 days. Vitamin B combinations 100 ml I/M for 5 days. Metamisole 10 mg/kg I/M for 5 days. Paraffin liquid 100–400 ml P/O *bid* at 2 days interval.	46	(Yüksek et al., 2002)
7.5	18	Diagnosis confirmed by abdominal palpation, radiography and exploratory proventriculotomy	Stress caused by transportation lead to ingestion of leaves, grass, wood or other fibrous materials	Surgery (Proventriculotomy and esophagotomy)	44	(Honnas et al., 1993)
4–6	7	Anorexia, dehydration, weight loss, a change in faecal consistency or production, and failure to respond to laxatives	Sand and rocks (N=5); hay and sand (N=1); leaves (N=1)	Surgery (Proventriculotomy)	71	(Honnas et al., 1991)
2–3	60	Mortality (N = 2), anorexia, drooping wings, defecations, messiness of feathers and inability to stand	Inexperienced farm workers and improper management lead to ingestion of rough feed particles, clover fibers, wood pieces, metal, glass, plastic, stone and sand	Surgery (N = 10) and medical therapy (N = 7) with vitamin B-complex (5 ml I/M), 5% dextrose – ringer lactate (50 ml/kg BW I/V) and liquid paraffin (100–200 ml *bid* P/O) for 3 days	Surgery = 80, Medical = 71	(Aslan et al., 2009)
4	58	Mortality (N = 3) and severe acute impaction (N=8) with anorexia, listlessness, emaciation, decreased defecation, separation from flock and recumbency	Stress of new farm along with improper stocking density, bedding, and management conditions lead to ingestion of sand, stone, pieces of wood, glass and plastic	Mineral oil and psyllium P/O *bid* for 3 days.	100	(Zakeri and Kashefi, 2011)
4–8	4	One dead (N = 1) and 3 alive birds showed signs of dehydration, pale mucous membranes, emaciation, sternal recumbency, outstretched neck and ruffled feathers	Improper management lead to ingestion of foreign bodies including stones, sand, spoons, wood fragments and ceramic tiles	Medical therapy (N = 3), oxytetracycline (250 mg/kg I/M), vitamin B-complex (2 ml I/M) and 5% dextrose saline (500 ml S/C)	67	(Ogbe et al., 2016)
2–5	50	General clinical signs of impaction diagnosed at a veterinary clinic	Mixed causes. Postmortem examination (N = 4) revealed compact balls of straw in proventriculus	Surgeries (N = 21) and conservative therapies (N = 29) with fluid therapy and broad spectrum antibiotics)	Surgery = 66, Medical = 86	(Verstappen, 1997)
24	1	Chronic weight loss, anorexia, lethargy and anemia	N/A	Surgery (Ventriculostomy)	100	(Jacobson et al., 1986)
2–6	506	Mortality	Transport and influenza A virus (H5N2)	N/A	N/A	(Jørgensen et al., 1998)

Age (months)	N	Clinical presentation	Etiology and risk factor	Treatment	Prognosis %*	References
1–3 (N = 2) 3–12(N = 12) 12–36(N = 6) >36(N = 5)	25	Autopsies of dead ostriches which showed signs of impaction including sternal recumbency, outstretched neck, debility, and inability to stand	Shifting from concrete to sand bedding	N/A	N/A	(Mushi et al., 1998)
8	1	Death	Idiopathic gastric stasis	N/A	N/A	(Ocal et al., 2006)
1	1	Gradual anorexia, lethargy, dehydration, weight loss, weakness, sternal recumbency and finally death	Sand bedding and pebbles	N/A	N/A	(Nagarajan et al., 2011)
2 >	8	Anorexia and acute onset of feebleness in three cases and chronic weight loss with anorexia and lethargy	Zygomycetes	N/A	N/A	(Jeffrey et al., 1994)
4	18	Dead birds (N=3) were autopsied after the signs of anorexia, scant faeces, chronic weight loss, weakness and lethargy	Zygomycetes, masses of sand, gravel, plastic and fibrous materials (hay, grass and leaves)	N/A	N/A	(Gulbahar et al., 2000)
3	1	Food pecking, weight loss, typical fungal lesions in the air sacs	*Aspergillus fumigatus* infection + ingestion of a large amount of gravel	N/A	N/A	(Sancak and Paracikoglu, 2005)
48	1	Respiratory symptoms	Aspergillosis	N/A	N/A	(Azizi et al., 2014)
4-6	2	Inappetance, weight loss, exercise intolerance, lethargy, and dehydration followed by constipation	Mixture of sand, stones and lucerne hay	N/A	N/A	(Sen and Albay, 2003)
0.2–2	300	12 birds died after showing the signs of stunning, anorexia and enlarged proventriculus	Zygomycsis and Norfloxcine	N/A	N/A	(Perelman and Kuttin, 1992)

* Percentage of recovered birds after treatment; N = sample size; N/A = not applicable; I/M = intramuscular; I/V = intravenous; S/C = subcutaneous; P/O = orally; *bid* = twice a day

(Aslan et al., 2009; Kumar et al., 2015). In chronic cases, the foreign material occupies physical space which severely limits feed intake resulting in signs of malnutrition, retarded growth, poor feathering, and leg abnormalities (Stewart, 1994; Komnenou et al., 2003; Speer, 2006). This obstruction may lead to further occlusion of the intestines, for example, multiple intussusceptions (Frasca Jr and Khan, 1997). Moreover, bacterial and mycotic enteritis are also associated with chronic impaction (Fig. 2).

Diagnosis: clinical presentation, histopathology and necropsy findings

The diagnosis of impaction depends upon clinical presentation, characterised by anorexia, emaciation, dehydration, decreased defecation, listlessness, cachexia, apathy, decubitus, lesser movement, exercise intolerance, separation from the flock, and recumbency (Honnas et al., 1991, 1993; Sato et al., 1994; Mushi et al., 1998; Deeming and Bubier, 1999; Yüksek et al., 2002; Komnenou et al., 2003; Sen and Albay, 2003; Speer, 2006; Nagarajan et al., 2011; Kumar et al., 2015) (Table 1). The skin of the bird may also appear pale (Ogbe et al., 2016). Palpation of impacted ventriculus on the left side of the abdomen is the simplest and an effective method of diagnosis. The proventriculus is located caudally to the ventriculus and along the midline and it can be palpated. After overnight withholding of food, it will appear soft in healthy ostriches and hard in birds with obstruction (Stewart, 1991). In addition, x-rays, ultrasound, gastroscopy, and laparotomy are also used (Honnas et al., 1991; Gamble and Honnas, 1993; Ocal et al., 2006). Aslan et al. (2009) reported that radiological examinations of ostriches suffering from impaction can reveal the extent of severity and guide further decision-making for treatment or surgical approaches. In most cases, the result is secondary gastric stasis leading to starvation and death (Yüksek et al., 2002; Kumar et al., 2015).

Table 2 shows the serum biochemical indicators in the ostriches suffering from gastric impaction. These changes occur due to tissue and systemic damage and starvation resulting from impaction (Mushi et al., 1998; Gulbahar et al., 2000). Yüksek et al. (2002) reported

Table 2. Blood chemistry and haematological profile* of normal and impaction affected ostriches with or without treatment

Measurement	Without treatment (Mean ± SD) [A]	Without treatment (Mean ± SD) [B]	Without treatment (Mean) [C]	After treatment (Mean ± SD) [A]	Normal ranges [D]
Erythrocyte (10^6/mm^3)	1.92 ± 0.6	-	-	1.96 ± 0.4	1.8 – 2.1
Leukocyte (10^3/mm^3)	10.4 ± 2.4	14.8 ± 2.5	-	16.6 ± 2.43	4-5
Platelets (/µL)	-	562 ± 75	-	-	200
PCV (%)	-	60.7 ± 4.3	-	-	36-43
Hematocrit (%)	33 ± 2.1	-	-	38 ± 1.68	30-40
Hemoglobin (g/L)	108 ± 2.9	-	-	13.4 ± 0.73	11-16
Glucose (g/L)	1.66 ± 0.48	2.67 ± 0.30	0.60	2.4 ± 0.63	1-1.4
Total protein (g/L)	24 ± 2.64	68 ± 19	22	38 ± 1.7	39–56
Albumin (g/L)	9 ± 0.9	30.3 ± 9	12	14 ± 0.71	18-20
Globulin (g/L)	15 ± 2.5	-	-	24 ± 1.4	27-30
Total bilirubin (mg/L)	2.5 ± 2.8	-	-	2.6 ± 0.9	1.4
ALP (µmol/L)	9.97 ± 0.1	6.62 ± 2.42	8.78	7.78 ± 0.16	2.5-9.6
AST (µmol/L)	6.97 ± 0.2	11.82± 5.7	-	3.58 ± 0.14	4.05-6.97
ALT (µmol/L)	0.27 ± 0.04	0.63 ± 0.32	-	0.31 ± 0.03	0.13-0.83
CK (µmol/L)	20.67 ± 0.28	-	-	10.23 ± 0.17	11.5–41.2
Amylase(µmol/L)	3.57 ± 0.07	-	-	3.24 ± 0.08	-
Urea (mg/L)	31.0 ± 2.45	98 ± 60	-	28 ± 2.24	23-36
Creatinine (mg/L)	4.00 ± 1.09	7 ± 3	-	4 ± 1	5-7
Ca (g/L)	0.1 ± 0.031	-	-	0.1 ± 0.05	0.10-0.18
P (g/L)	0.04 ± 0.031	-	-	0.06 ± 0.04	0.11-0.14
Mg (g/L)	0.03 ± 0.045	-	-	0.02 ± 0.04	0.02-0.03
Zn (mg/L)	1.210 ± 0.6	-	-	1.437 ± 0.5	0.6-1.6
Cu (mg/L)	0.86 ± 0.64	-	-	1.12 ± 0.47	0.2-0.5
Na (mEq/L)	140.0 ± 4.3	-	-	141.1 ± 3.7	147–157
K (mEq/L)	4.8 ± 0.63	-	-	4.7 ± 0.55	3-3.5
Cl (mEq/L)	102.4 ± 3.1	-	-	101.2 ± 2.1	100-104

*Values were adapted from literatures sources: [A] (Yüksek et al., 2002)emaciation, decreased defecation, listlessness, separation from the flock, and recumbence. The total number of leukocytes (10.4 × 103 mm3, [B] (Komnenou et al., 2003), [C] (Mushi et al., 1998), [D] (Bonadiman et al., 2009; Durgun et al., 2005; Mushi et al., 1999; Polat et al., 2004; Shanawany and Dingle, 1999; Siwela et al., 2004; Verstappen et al., 2002). ALP = alkaline phosphatase, AST = aspartate aminotransferase, ALT = alanine aminotransferase, CK = creatine phosphokinase, PCV = packed cell volume. The enzyme activity values were converted from U/L to µmol/L) using "unitslab.com"

blood chemistry and haematological analysis results, including an increase in the concentrations of creatine kinase (1240 U/L) and alanine phosphatase (ALP; 598 U/L) and a decrease in the concentrations of glucose (1.66 g/L), total protein (24 g/L) and total leukocytes (10.4 × 10^3/mm^3). Mushi et al. (1998) also reported similar findings of hypoglycaemia, hypoproteinaemia and hypoalbuminemia, and increased ALP. At this stage, the immune system can be severely compromised, especially in cases of fungal infections, and secondary infections may also develop (Ocal et al., 2006).

Post-mortem findings are marked by dehydration, emaciation, and an enlarged, rigid, and doughy gizzard which occupies most of the abdominal cavity with focal haemorrhagic adhesions (Shwaluk and Finley, 1995; Mushi et al., 1998). Other gastric lesions reveal oedema, erosions (Yüksek et al., 2002), and haemorrhagic ulcers as shown in Fig. 3.

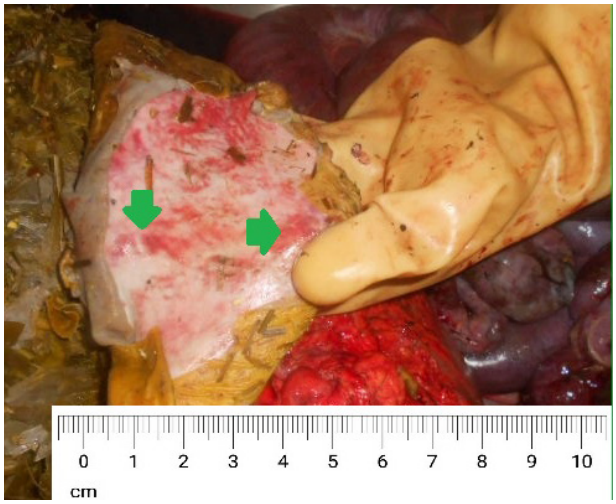

Figure 3. The *post–mortem* haemorrhagic lesions (marked by arrows) on the gizzard wall of a 14 month old adult ostrich, ©Authors

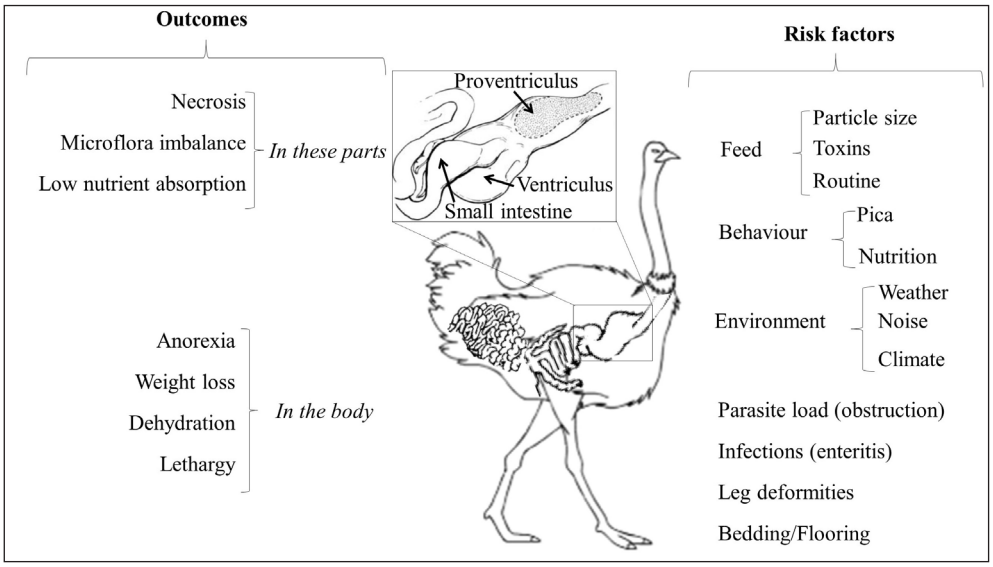

Figure 4. The possible causes and risk factors and outcomes of gastric impaction in ostriches. Parts of Figure are adapted from Langlois, (2003) and Brand and Olivier (2011)

In a histopathology study of gastric impacted ostriches, Ocal et al. (2006) observed that the epithelial lining of glands in the proventriculus was hyperplastic, characterised by luminal buds and irregular proliferation resulting in swelling of mucosa. Hyperplasia was further confirmed by the presence of a higher number of epithelial cells, showing that approximately 90% of cells were actively dividing in gastric impacted ostriches as compared to control where this number was close to 35%. The authors attributed those changes to the response to the physical strain on the proventricular wall caused by impaction.

The presence of fluids in the intestine can be observed in some cases when the feed passage is blocked and the fluids are still passing through the stomach (Sato et al., 1994). The intestinal exudates are dark-coloured (Nagarajan et al., 2011) and the mucosa shows haemorrhages (Kumar et al., 2015; Ogbe et al., 2016). Cloacal prolapse has also been observed in impacted ratites (Iordanidis et al., 2003; Akinrinmade and Eyarefe, 2011), especially in mycotoxicosis-related impaction cases (Gulbahar et al., 2000). However, there are other reasons of cloacal prolapse also, for example, *Cryptosporidium* sp. infestation (Santos et al., 2005).

The pericardium of the heart is oedematous and contains gelatinised fatty tissue (Nagarajan et al., 2011), with atrophy of coronary fat (Mushi et al., 1998). Hepatic tissues may have sinusoidal congestion (Nagarajan et al., 2011). Depending upon the cause of impaction, the lesions may vary; for example, gastritis due to the presence of parasites under the proventriculus membrane (Iordanidis et al., 2003; Ocal et al., 2006; Sánchez-Ayala et al., 2018) and caseous nodules resulting from tuberculosis and aspergillosis (İçen et al., 2011; Azizi et al., 2014; Bello et al., 2017).

Risk factors leading to gastric impaction

Impaction can be a simple obstruction of the GIT tract or a complication originating from other diseases. Generally, it is regarded as a management-related problem, especially during young age or the rearing period between three and six months (Verstappen, 1997; Mushi et al., 1998; Gulbahar et al., 2000; Zakeri and Kashefi, 2011; Ogbe et al., 2016). Honnas et al. (1993) reported that the median age of ostriches suffering from impaction was 7.5 months ranging from few weeks-old juveniles to 18-year-old adult ostriches. If the birds are not properly managed, they are exposed to stress, leading to ingestion of excessive food or inedible material, ultimately leading to obstruction of GIT (Huchzermeyer, 1999; Hernández-Arroyave and Bustamante-Cano, 2019). The following risk factors of this obstructive disorder may influence its occurrence singly or in complex combinations (Fig. 4).

Nexus of behaviour and stress

Ostriches differ in behaviour which is linked to the age of birds, time of day, and season (Amado et al., 2011). This curious bird picks on everything that appears shiny or unusual to them (Huchzermeyer, 1997). This pecking behaviour often leads to the ingestion of some inedible materials which can cause gastric impaction (Zakeri and Kashefi, 2011).

Apart from this curiosity-seeking behaviour, ostriches often have peculiar behaviour during winter months, causing serious problems in cases of extreme confinement (Huchzermeyer, 1997). This abnormal behaviour including dietary indiscretion and *pica* may begin with inadequate husbandry techniques, ultimately becoming a medical problem because of its severity (Shanawany and Dingle, 1999).

Dietary indiscretion is the tendency of ostriches or other birds to peck at unusual materials and ingest them (Samson, 1996) and these items are often relatively small foreign objects not found in their natural habitat, and therefore, mistakenly ingested owing to a familiar flavour, or as simple curiosity (Honnas et al., 1991; Gamble and Honnas, 1993). Common ingested materials include whole sawdust, sand and straw used as bedding, hardware used in pen and fence construction, rocks, and grit. This behaviour results in gizzard impaction, stasis (Huchzermeyer, 1997), and even perforation of GIT if sharp objects are ingested (Stewart, 1991). Generally, it is believed that ostriches eat only what is good for them, however, the existence of so many impaction cases indicates a tendency towards indiscriminate behaviour that elicits obstructions (Shanawany and Dingle, 1999; Hernández-Arroyave and Bustamante-Cano, 2019).

On the other hand, *pica* is believed to be a behaviour linked to mineral deficiency in birds (Samson, 1996). The young ostrich birds ingest faeces of elder birds as a natural behaviour, likely to enrich their healthy intestinal microbiome, and obtain protein, fibres and minerals (Shanawany and Dingle, 1999). Conversely, in captivity, this behaviour could lead to ingestion of excessive amounts of droppings (Deeming and Dick, 1995), especially when there is a confined space and bedding is a hard substrate. As result of this behaviour, the beak of chicks may become obstructed with faecal material and microbial infections can lead to systemic problems such as respiratory illnesses (Samson, 1996; Deeming and Bubier, 1999).

Stress in birds renders them prone to many undesirable outcomes which result in production losses in poultry (Huchzermeyer, 1997). The environmental stress factors include temperature, humidity, handling, transport, stocking density, noise, poor access to feed, hierarchical dominance, and presence of predators around the farm (Deeming and Bubier, 1999; Shanawany and Dingle, 1999; Bejaei and Cheng, 2014; Navarro et al., 2019). These environmental factors influence the feeding behaviour of ostriches and can lead to development of conditions like *pica* (Samson, 1996). If the birds are off feed due to any of these stressful events, they start pecking on inedible material which ultimately gets stuck in the stomach (Honnas et al., 1991; Farzi, 1992; Gamble and Honnas, 1993; Huchzermeyer, 1997; Samson, 1997).

In a different scenario, when a bird obtains access to feed after a long stressful pause, it starts gorging food rapidly, increasing the danger of impaction (Shanawany and Dingle, 1999). Shwaluk and Finley (1995) also reported that stress-related gorging with chopped alfalfa and straw (2–4 cm) caused proventriculo-ventricular impaction in ostrich chicks. Honnas et al. (1991) and Sato et al. (1994) reported that transportation stress in young ostrich birds was responsible for gorging and ultimately gastric impaction.

Feed contamination and other predisposing biotic factors

Feed and feeding are the most important factors in the success of any farming system. The contamination of feed with foreign objects such as rocks or nails leads to impaction in ostriches (Shanawany and Dingle, 1999). Additionally, the lack of feed or water during a proper routine and its location in the shed can render birds to develop a habit of picking on inedible materials (Deeming and Bubier, 1999; Yüksek et al., 2002). This type of situation severely stresses birds, leading to an obstruction of the gizzard from ingestion of such materials (Mushi et al., 1998). Dry matter and higher fibre content, and bigger particle or chop sizes of these fibres are also responsible for stomach obstruction (Mushi et al., 1998).

Feed contamination with mycotoxins is also a risk factor for impaction development in ostriches (Fitzgerald and Moisan, 1995). Mycotoxicosis is one of the major causes of mortality in ostrich farming regions (Katz et al., 1996), and it is difficult to diagnose and hinders treatment of individual ostriches (Hereba et al., 2016). Systemic fungal infections cause localised lesions in different systems (İçen et al., 2011), and induce stress in birds (Hereba et al., 2016). In the case of the GIT tract, inflammation and granule formation influence digestion and the absorption process (Perelman and Kuttin, 1992; Jeffrey et al., 1994; Gulbahar et al., 2000; Bello et al., 2017). Studies have reported impaction occurring in ostrich chicks as result of proventriculitis and ventriculitis caused by zygomycotic fungi, e.g., *Mucor* spp., *Aspergillus* spp., and *Penicillium* spp. (Jeffrey et al., 1994; Gulbahar et al., 2000). Sancak and Paracikoglu (2005) reported that *Aspergillus fumigatus* caused infection of the respiratory system and induced stress in ostrich chicks. Consequently, ingestion of a large amount of gravel blocked the passage from the proventriculus and ventriculus, and the combination of both conditions resulted in death. Similarly, concurrent aspergillosis and impaction were reported in a 4-year-old ostrich that was principally showing respiratory symptoms (Azizi et al., 2014).

Enteritis can be a predisposing factor for the development of impaction, and it can also occur because of gastric obstruction (Shanawany and Dingle, 1999; Cooper, 2005). Stressful events in ostrich production can influence the intestinal microbiome of birds (Videvall et al., 2019a). When conditions are favourable for certain opportunistic pathogens, they can cause enteritis (Riaz et al., 2017). Many biotic factors can cause inflammation of GIT; however, the primary causes are bacteria e.g. *Escherichia coli*, *Campylobacter jejuni*, *Pseudomonas aeruginosa*, *Salmonella*

spp. and *Clostridium* spp. (Huchzermeyer, 1997; Buergelt, 2000;Verwoerd, 2000; Videvall et al., 2019b). Among these, enteritis due to *Clostridium difficile* and *Clostridium perfringens* are common findings in neonatal ostrich chicks (Samson, 1997; Cooper, 2005).

Endoparasites in GIT can block the flow of ingested feed and result in impaction (Shanawany and Dingle, 1999; Cooper, 2005; Mendonça et al., 2010; Nemejc and Lukesova, 2012). Some parasites may even perforate the GIT; for example, *Libyostrongylus douglassii* resides in the gastric layers of ostriches (Sánchez-Ayala et al., 2018) and heavy infestation of this parasite obstructs feed passage, especially in young chicks (Shanawany and Dingle, 1999).

Some viral diseases are also responsible for impaction in ostriches. Jørgensen et al. (1998) found that impaction of the proventriculus and gizzard was a consistent finding in dead ostriches that were later diagnosed with influenza A virus (H5N2) and paramyxovirus type 1 infection. In another study, paramyxovirus serotype 7 was isolated from a juvenile ostrich that originally presented with impaction complications (Woolcock et al., 1996). Similarly, an investigation of gastric impaction and enteritis in ostrich chicks led to isolation of infectious bursal disease virus (Gough et al., 1998).

Treatment approaches

Once a bird is diagnosed with impaction, several treatment options can be implemented depending upon its severity. If the bird has a history of ingesting objects or radiography confirms the ingestion of fibres or small pieces of foreign materials, the objective of therapy is to pass these materials from the stomach (Shanawany and Dingle, 1999). Laxatives can serve this purpose by breaking up the hard, congested mass of impacted material. Feeding ostriches with a demulcent like mineral oil (3–6 mL/kg body weight) along with some purgative or laxative (i.e., psyllium or liquid paraffin) for 2–3 days can help the affected birds recover (Sato et al., 1994; Samson, 1997; Mushi et al., 1998; Zakeri and Kashefi, 2011). Epsom salt (magnesium sulphate) is another laxative for relieving partial obstructions in ostriches (Shanawany and Dingle, 1999; Aganga et al., 2003). The recovery rate depends on the severity of the condition and choice of treatment (Table 1). For example, multiple studies reported 100% recovery via oral feeding of mineral oil (Sato et al., 1994; Zakeri and Kashefi, 2011), but Yüksek et al. (2002) showed that even after using a combination of different medical therapies (fluid therapy, antibiotics, multivitamins, and laxatives), only 46% of impacted ostrich chicks survived.

If birds do not respond to the treatments mentioned above, the impaction is considered an emergency situation and requires surgery (Shanawany and Dingle, 1999). A decision of proventriculotomy can be made based on an impaction diagnosis via palpation and radiography or exploratory surgery can be performed (Gamble and Honnas, 1993; Komnenou et al., 2003). Mushi et al. (1998) recommended that proventiculotomy can be attempted at the earliest stages of impaction. Delay of a surgical decision can lead to GIT atony, ulceration, and candidiasis of proventriculus (Stewart, 1991). Moreover, ostriches at later stages of impaction are already emaciated and they do not survive the stress of a surgical intervention (Munir et al., 2015; Ogbe et al., 2016). Stewart (1991) reported that after early detection, chicks could be brought back to the flock just a day after surgery. Shwaluk and Finley (1995) reported a successful surgery with good prognosis when a 15-day-old ostrich chick presented at the hospital with a 12-hour history of emaciation, poor activity, scant faeces, and not responding to treatment with mineral oil. In a retrospective study involving 21 surgeries, Verstappen (1997) reported that two-thirds of the ostriches treated with a modified proventriculotomy approach recovered successfully, whereas the survival rate from conservative therapy (fluid therapy, forced feeding via oesophageal tube if needed and use of broad spectrum antibiotics) was 86% after 14 days of follow-up. This difference in prognosis is difficult to explain because of the distinct clinical conditions of birds.

In all types of impactions, whether they require surgical treatment or not, managing stress and dehydration is important (Verstappen, 1997). For this purpose, parenteral or oral fluid supplementation together with supportive therapy is recommended in affected birds (Deeming, 1999; Yüksek et al., 2002; Komnenou et al., 2003). Studies state that birds recover from severe impaction with just symptomatic treatment including 5% dextrose and 0.9% saline solution, vitamin B-complex, and oxytetracycline or amoxicillin plus clavulanic acid, or metamizole and liquid paraffin for 2–5 days (Yüksek et al., 2002; Ogbe et al., 2016). Similarly, antibiotic therapy, fluid therapy (Lactated Ringer's solution), supplementation (antioxidants), and soft food are recommended for surgically treated ostriches (Shwaluk and Finley, 1995; Verstappen, 1997; Komnenou et al., 2003; Munir et al., 2015).

As impaction can occur simultaneously with mycotoxicosis (Sancak and Paracikoglu, 2005)then a treatment of fungal infection is also needed. Common anti-fungal agents including nystatin, amphotericin-B, flucytosine, ketoconazole, itraconazole, fluconazole, and enilconazole are used for treatment of aspergillosis (İçen et al., 2011). Focal aspergillosis shows a better response to treatment; however, the generalised form which may involve impaction requires a longer treatment period (Sancak and Paracikoglu, 2005). İçen et al. (2011) reported that the treatment with amphotericin B and a commercial biostarter [Akpe Biyomaya ingredient (SCC 3.5 × 10 CFU, Active Clinoptilolite 500.000 mg, Biotin 1.3 (U/g), Thiamine

60–100 (U/g), Riboflavin 35–50 (U/g), Pantothenate, 70 (U/g), Folic acid 5–13 (U/g), Choline 4.000 (U/g), Niacin 300–500 (U/g)], in aspergillus-infected ostrich chicks, showed good outcomes.

Control and prevention

Impaction is caused by both direct and indirect factors and they should be addressed accordingly. Direct factors are ingestion of feed and foreign objects (Deeming and Bubier, 1999). Bigger fibres and particle sizes, and high dry matter content should be avoided; it is recommended to chop the fodder into smaller sizes depending upon the age of bird (Shanawany and Dingle, 1999). The farm area should be kept free of small-sized foreign materials that could be accidentally ingested. As the birds eat bedding material (Munir et al., 2015, 2019a, 2019b; Sato et al., 1994), covering the bedding of juvenile birds can avoid ingestion of sand or other bedding material, or even the faeces of elder birds (Mushi et al., 1998; Nagarajan et al., 2011). In addition, special care should be given when birds are shifted from one type of bedding to another (Yüksek et al., 2002; Akinrinmade and Eyarefe, 2011), especially if it is a completely different type of bedding material. Mushi et al. (1998) reported that shifting of ostriches from concrete to sand bedding caused sand impaction. To prevent excessive *pica* and encourage birds to eat offered feed, faeces and inedible foreign materials should be removed from pens on a regular basis, and chicks should be provided with toys or appropriate fibrous material in small amounts for pecking (Deeming and Dick, 1995; Farzi, 1992). In an experimental study it was observed that shifting the adult ostriches to newer pens reduced the sand consumption behaviour, probably because they spent more time in exploring the new environment and marking their territory (Yen, 2008). Mushi et al. (1998) stated that impaction cases decreased when birds had adequate access to feed. Chicks learn to eat under natural wild conditions by copying their parents' feeding behaviour (Aganga et al., 2003). Therefore, similar arrangements should be maintained in captivity, such that a foster mother (Mukhtar et al., 2017) or a well-trained bird that is just a few days older may be put in with flocks of younger birds (Aganga et al., 2003). In addition, green fodder and green-coloured feeding trays are usually preferred by ostriches and their use enhances feed consumption resulting in good efficiency of feeding.

Indirect factors are influencers that can either cause stress in birds or induce impaction as a secondary situation (Deeming and Bubier, 1999). Firstly, stress causes improper ingestion of feed and foreign materials, therefore it is recommended to keep the birds stress-free, and give special attention to birds in any unwanted stressful events (Samson, 1996; Shanawany and Dingle, 1999; Cooper, 2005; Iqbal et al., 2015). The stress-causing factors may be noise, fear of predators, diseases, climatic conditions, and malnutrition. Avoiding these situations can help to keep the impaction problem at a minimum. Moreover, gentle human interactions with ostrich chicks at early age can be beneficial in reducing sensitivity to physiological stress and increasing their ability to distinguish between familiar and unfamiliar handlers (Muvhali et al., 2018, 2020). Therefore, a clothed dummy can be placed in the chicken runs to give the impression of security (Mushi et al., 1998). Apart from these measures, the birds should be provided with space for running and exercise which also reduces the danger of impaction by increasing intestinal motility and blood circulation (Shanawany and Dingle, 1999).

Stress due to pathogens and diseases can be minimised by addressing each agent accordingly. Mould-free feed is a good way to avoid mycosis-related impaction (Sancak and Paracikoglu, 2005; İçen et al., 2011). If mould contamination is expected due to seasonal conditions, the birds should be fed toxin binders in their feed. Birds may develop behaviours of anorexia and adipsia after exposure to mycotoxin-contaminated feed, therefore this issue should be prevented to avoid production losses. Prophylactic anti-parasitic therapy is also a good option to reduce parasitic burden. However, these drugs should be administered after a positive diagnosis to avoid pathogenic drug resistance (Nemejc and Lukesova, 2012). In the case of enteric infections in a flock, preventive measures of providing antioxidants and digestible feed must be ensured (Rehman and Munir, 2015). Probiotics can also be given to improve healthy intestinal microbiome (Riaz et al., 2017).

CONCLUSIONS

The impaction affects the ostriches of all ages, however, the juveniles are at higher risk. The abnormal ingestion of feeding and non-feeding materials are the main causes of impaction and it is inflicted by various stressors such as, noise, bedding, leg deformities, infections and parasitic infestations.

After successfully diagnosing the impaction via palpation or radiography, the medicinal or surgical treatments can reduce morbidity and mortality rates along with improvement of welfare of birds. However, further studies are needed to provide a risk benefit analysis of treatments to establish the economic value of these remedies.

Preventive measures are mainly linked to management practices, which are supposed to reduce stress and the availability of inedible objects at an ostrich farm or sanctuary. Meanwhile, behaviour related feeding training of ostriches by leaving the chicks with elder birds or foster parents can reduce the chances of impaction. The young ostriches also require attention

of handlers, and dummies can serve this purpose to some extent.

Future studies should explore the predisposing factors of genetics of birds and the intestinal microbial diversity, which could have a potential influence on the occurrence of impaction in ostriches.

CONFLICT OF INTEREST

We declare that there is no conflict of interest.

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