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# Use of Mannan- Oligosaccharides (MOS) As a Feed Additive in Poultry Nutrition

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## ABSTRACT

The European Union banned using all prophylactic antibiotics as growth promoters in poultry nutrition. As a result, the poultry nutritionist is now forced to look for growth promoting antibiotic alternatives, or at least considerably demote the amount of antibiotics used to sustain efficient broiler meat production and to be able to produce safe poultry egg and meat products. The Mannan-oligosaccharides (MOS), is a type of probiotics originated from the yeast cell wall (*Saccharomyces cerevisiae*) has gained more prominent attention, mainly due to its ability to bind the threadlike fimbriae on pathogenic bacteria preventing them from attaching to the gut wall, thereby averting their stabilization and the resulting colonization and multiplication, up to the disease level, so it had been showed to be a most capable solution for antibiotic-free diets, as well as furnishing effective support for digestion and immunity in poultry. Several investigations confirmed that using MOS as a feed supplement in poultry diets allowed birds to achieve a similar trend as when they were fed a diet enriched with antibiotic growth promoters. In addition, MOS has also shown to have a positive affection on bodyweight gain, feed conversion ratio, egg weight, egg production, fertility, and hatchability thus ameliorating well-being, energy levels and performance of avian species. Furthermore, it is also thought that it plays a role as an antioxidant, helping with mineral retention, improving bone mineralization and subsequently the overall improvement the performance of poultry birds. This review article has aimed to illuminate its sources, mode of action and beneficial applications of MOS in poultry diet for improving, production, immunity, safeguarding health among consumers and it ought to be used as a natural growth promoter on a commercial level in order to replace synthetic antibiotics in the poultry industry.

**Key words:** Antioxidant, Feed additive, Gastrointestinal health, Mannan-oligosaccharides (MOS), Performance, Poultry

## INTRODUCTION

In the past decades, a variety of feed accretive had been employed in poultry diet. These feed accretive led to an improved rendition and effective utilization of feed in poultry birds (Chand et al., 2016a; Shah et al., 2016; Xing et al., 2017; Saeed et al., 2017a, b). Routinely being utilized in accretive of feed as: emulsifiers, antimicrobials, antioxidants, biological products, herbs, pH control agents binders and enzymes as well (Vahdatpour and Babazadeh, 2016; Siyal et al., 2017; Tareen et al., 2017; Saeed et al., 2017c, d, e).

Growth promoting is not the only use of feed additives but they have used also for stabilizing the

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beneficial gut microflora by forestalling beneficial microorganisms (Hashemi and Dawoodi, 2011; Abudabos et al., 2017). In the last decades, antibiotics that are used as growth promoters in animal feed have been under severe attention, since they pose a potential threat to consumers by generating resistance in the host against the bacteria (Sultan et al., 2015). Conclusively, the European Union had banned the supplementation of growth promoting antibiotics in the animal diet since 2006 (Khan et al., 2016). Now, it is most important for the poultry researcher to find alternatives to antibiotic growth promoters to boost the health andproduction performanceof poultry birds (Janardhana et al., 2009; Babazadeh et al., 2011; Vahdatpour et al., 2011). Feed additives of plant origin have gained a great interest in the poultry industry as they are safer, with wide dose range and so rare adverse effects (Alzawqari et al., 2016; Abudabos et al., 2016). Recently, many experiments had shown a number of significant effects on growth parameters, immune response and gut health status in birds fed diets contain phytogens (Tanweer et al., 2014; Saeed et al., 2015; El-Hack et al., 2016, Saeed et al., 2017f, g , h). These studies have shown that the small intestine with the main role in the absorption of nutrients; it then proves that, both the proper structure and the proper function of the intestine is efficient in improving poultry performance and health (Sultan et al., 2014). It has been suggested that intestinal digestion and absorption of the nutrients is higher if the surface area of the villi is increased (Chand et al., 2016b). The beneficial microflora of young birds gut's are counted to be somewhat irregular and can easily be disturbed by several external factors. The subclinical infection is one of these external factors which posed by the pathogenic challenge. So, the ability to preserve an optimal or normal level of beneficial microflora in the gut becomes one of the main factors in the determination of the ultimate health status and consequently the genetic growth expression of poultry. At commercial basis, available mannan-oligosaccharide has exhibited to enhance the bird growth parameters including feed intake and feed utilization (Hooge, 2004a; Rosen, 2007a, b; Nikpiran et al., 2013). The beneficial impacts of MOS on the development gut microflora were also revealed by Kocher et al. (2005) and Yang et al. (2008). The addition of MOS constantly elevates the caecal beneficial populations like *Bifidobacterium* and *Lactobacillus* spp. (Sadeghi et al., 2013). Decreasing the pathogenic bacteria and the increasing the beneficial bacteria could be belonged to the receptor sites competition and producing volatile fatty acids by bacteriocins along with IgA antibodies by the host immune system (Kim et al., 2009). Owing to these changes in the beneficial microflora, the goblet cells number and intestinal villi length increase as well, which ultimately promotes functions and health of the host GIT (Bonos et al., 2010). The diet supplemented with MOS has been reported to have a positive effect regarding body weight, feed efficiency, egg yield, fertility, egg mass and egg hatchability in various poultry species (Guclu, 2011; El-Samee et al., 2012). In another study by Iqbal et al. (2017) who had fed birds with MOS that had significant effects on body and egg mass, egg weight, and egg number and it has shown that feeding MOS as a substitute for antibiotics, as growth enhancer, can positively impact productive traits as well as health aspects in breeders of quail. This can also improve the manifest utilization of energy in feed and improvethe birds feed efficiency that could partially belong to the modulatory impacts of mannan-oligosaccharide on the GIT microflorain broilers (Yang et al., 2008). The current review article discusses the potential aspects of using MOS; including its sources, mode of action and beneficial applications of MOS and its practical uses in the nutrition and production of poultry industry for improving, production, immunity and safeguarding health, among consumers and to prioritize this natural growth promoter as opposed to synthetic antibiotics to cope the medicinal cost in poultry.

**Chemical traits and source of mannan-oligosaccharides**

Mannan-oligosaccharides originated from the mannose blocks that exist in the yeast cell wall as it is mostly non-digestible carbohydrates (*Saccharomyces cerevisiaeis*). The cell wall consists of up to 25–30% of cell dry weight. The *Saccharomyces cerevisiae* is known yeast in the brewery and bakery industries. The MOS product which is a derivative of the yeast is used in animal nutrition. *Saccharomyces cerevisiae* cell wall involves both α-glucans and mannan-proteins. The essential building block for yeast cell wall are polymers of mannan with α (1-2) and α (1-6) bonds and to a less extent α (1-3) bounded side chains (Kogan and Kocher, 2007). The host enzymes or the intestinal bacteria enzymes cannot break these bonds apart and as a result carbohydrates (MOS) have no direct nutritive value, but it has benefits in keeping the gut health. It can be theorized from the several scientific research work that although mannan as a derivate from yeast (*Saccharomyces cerevisiae*) is attributed to production and processing technologies, it might have different chemical formation and biological efficiency as reported by Spring (1999).

### Mode of action

The beneficial microbiota development and the sustainment of eubiosis act an important role in the mechanisms of defense in the body and health of gut as well. There is elevating evidence confirming that the composition of microflora in the gastro intestinal tract in an adult healthy host remains statistically stable as theorized by Williams et al. (2001). Results of current studies suggesting that the supplementation of MOS to poultry diets can minimize the count of hind gut pathogenic bacteria during the high exposure to the pathogen (White et al., 2002; Castillo et al., 2008). The MOS supplementation was indeed accompanied with increasing beneficial flora, especially *lactobacilli* (Rekiel et al., 2007). Another experiment has also confirmed the beneficial impact of MOS, however, it has been also found to decline animal gut concentration of ammonia (Juskiewicz et al., 2003). Literature documented data indicated that dietary MOS fed diets can greatly lower the number of pathogens. In some studies on poultry, proves found that if the dietis supplemented with MOS a considerable positive effect on gut histological structure in broilers chicken (Iji et al., 2001a). Similarly, it is reported that dietary supplementation of mannan products had the effect of increases the ratio of villous height/crypt depth in young broilers (Iji et al., 2001a; Yan et al., 2008) and in turkeys as well (Ferket, 2002) (Figure 1). Nochta et al. (2010) found that the addition of mannan as feed supplement remarkably enhanced the nutrients apparent digestibility.

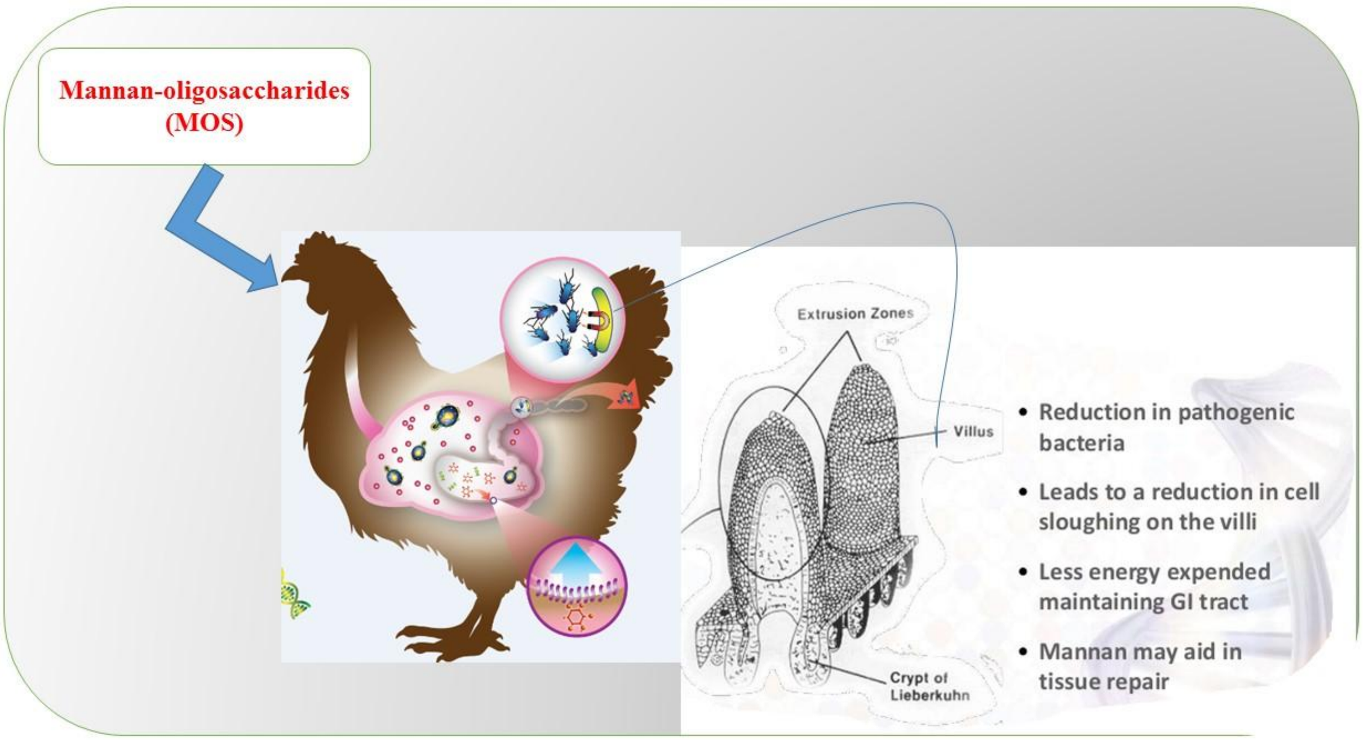


**Figure 1**. How do Mannan-Oligosaccharides (MOS) affect intestinal structure (MOS could prevent the colonization and attachment of pathogenic bacteria and thus reduce the adverse effects of microflora and metabolites)

### Beneficial effects of mannan-oligosccharides in poultry

***Broiler Farming***

***Effect on growth performance and blood biochemistry.*** Mannan-oligosaccharide that is one of the best alternatives to antibiotic growth advancers in the poultry industry diets and which are originated from yeast outer cell wall that known as *Saccharomyces cerevisiae* (Eseceli et al., 2012). The use of MOS in broiler diets had shown to positively impacts on performance criteria (Rosen, 2007a; Fritts and Waldroup, 2003). The range of dietary inclusion of the MOS averaged from 0.5 to 5 g /kg diet. The dose-response of MOS in different research work had showed the best dosage of MOS for optimal growth is around 2 g /kg diet as reported by Tucker et al. (2003). Iji et al. (2001b) studied the influences of different doses of MOS (0, 1, 3 and 5 g /kg diet) on the structure and function of the intestine of poultry birds within the starter period (21-day). Results proved that poultry birds gave a high response by increasing the addition of MOS from 1 to 21 d compared to the 21-42 d period (Tucker et al., 2003). Nikpiran et al. (2014) reported that adding the MOS to the diets of poultry improved the growth performance values by enhancing the feed intake and stimulating the growth hormone and insulin release.

In a study had reported a significant decrease in the total cholesterol concentration in broiler chickens which had been supplemented with MOS @ 0.05% when compared to a control diet (Juskiewicz et al., 2003). Also, another experiment had shown that MOS could promote caecal *Lactobacillus* spp. and *Bifidobacterium* spp. growth and also elevated the height of villus and the number of goblet cells in poultry jejunum and ileum (Mohsen et al., 2014).

***Effect on immune response.*** It is found that MOS had proved to be much more effective on antibody production against Avian Influenza Virus (AIV) in broiler chickens than Humate (HU). The immune function could be augmented with dietary Humate and MOS supplementation (Tohid et al., 2010). The innate immune system recognizes key molecular formations of the invading bacteria involving peptidoglycans, lipopolysaccharides, and possibly the structures of mannose in the cell walls of yeasts. Oligosaccharides which have mannose have been reported to impact on immune system through activating mannose-binding protein secretion from the liver. The aforementioned protein, as a result can enchain to bacteria and trigger the complement cascade of the immune system of the host as described by Newman (1994). MOS was indicated of having a beneficial effect on both immunoglobulin status and humoral immunity in general. Savage (1996) described an increase in IgG of the plasma and bile IgA in poultry grown up on diets supplemented with 0.11% MOS. The diet fed with MOS may constitute a novel and most effective plausible alternative that could reduce the spread of disease by decreasing the virus shedding and the contamination of the environment from AIV ($H_9N_2$) infection in poultry birds (Akhtar et al., 2016). Both *Saccharomyces cerevisiae* and its derived product is known as MOS that supplementation in poultry feed has a clear effect on the attenuation of *Escherichia coli* (*E. coli*) which induces intestinal cells disruption by reducing the intestinal inflammation and barrier dysfunction in broilers chicken. In addition to that, yeast (*Saccharomyces cerevisiae*) addition could also improved the intestinal microbiota and feed efficiency of in avian species (Wang et al., 2016) and MOS could improve the absorption of trace minerals (Sohail et al., 2011).

***Layer farming***

The feed supplementation with MOS has shown to entail positive effects by improving ($P < 0.01$) the liver antioxidant status and mitigating the significant increase in the cecal pathogenic bacterial load after molt in layer birds which shows the benefits of which can be improved with MOS supplementation (Bozkurt et al., 2016). The prebiotic (mannan-oligosaccharide) supplementation can positively alter the intestinal microenvironment (Hutsko et al., 2016). In another study by Jahanian and Ashnagar (2015) found that MOS supplementation to laying hens feed under bacterial infection could improve their productive performance probably through modification in the gut’s bacterial populations and improving nutrient digestibility. As described by Bozkurt et al. (2012) who had shown that egg production had efficiently improved by MOS also showed that a stimulating humeral immune response in laying hens in different climate conditions.

***Turkey farming***

After the broiler production industry, the turkey industry considered as the second source of poultry meat across the globe. In turkeys, 76 numbers of comparisons showed the same responses to MOS as in broilers (Hooge, 2004b; Rosen, 2007b). Hooge (2004b) claimed that MOS addition to turkey rations revealed an average increase in body weight by2% and reductionmortality by about25%.

So, organic enteric conditioners, such as dietary MOS, are of great importance for the turkey farming industry. Recently, antibiotic resistance had been raised in the *Escherichia coli* exist in the field which had been isolated from commercial turkey farms in North Carolina. In addition to that, a resistance to the Enrofloxacin had been showed (Bernick et al., 1999). There is no specific proof that that growth promoting doses of antibiotics control disease (Gustafson and Bowen, 1997), the debate over the Gram-negative bacteria that had been showing some resistance, as shown by *Salmonella* and *E. coli*, which caused the strongest objection to the use of antibiotic as growth promoters (Scioli et al., 1983). MOS improves the performance of turkey poults, especially during the *E. coli* challenge like antibiotics which were traditionally used (Ferket et al., 2002). An improvement in growth performance was also observed in turkeys fed diets enriched with MOS (Savage and Zakrzewska, 1996) also authors found a statistical increase in body weight gain in large white male poults which fed a diet supplemented with 0.11% MOS. Cetin et al. (2005) reported that MOS enhanced immunoglobulin levels and caused more positive effects on growth performance, production and the turkeys' ability to resist diseases. As a result of the previous finding, it can be concluded that MOS is an interesting alternative to antibiotic growth promoters to improve performance in turkey (Parks et al., 2001) and also it has a clear effect on improving body weight gain and lowering mortality in poults (Hooge 2004a).

**An alternative to antibiotic**

In contrast, regarding the action mode of the chemical growth promoters (antibiotics) fermentable carbohydrates sources, oligosaccharides especially MOS, act as one of the best alternatives to the Gram-negative pathogens attachment sites, so they prevent the attachment to the enterocytes and subsequently prevents the enteric infection. The adherence step of the pathogenic microbe to the intestinal cell wall is known to be the prerequisite step to the infection (Gibbons and Houte, 1975). This can be more clarified as in Vibrio cholera which is incapable of starting their disease signs without the attachment step to the enterocyte, even with large numbers of bacteria present (Freter, 1969). The adhesion step causes the bacterial entrapment and colonizing. The entrapment of nutrients for growth, the concentration of the digestive enzymes and the toxins onto intestinal cell wall, and the possible prevention of antibody attachment to the pathogenic cell (Costerton et al., 1978). The cell wall of the yeast organism is mostly carbohydrates and proteins in the form of mannose, glucose, and N-acetylglucosamine that are branched and chained together (Ballou, 1970). Mannan-oligosaccharides that are derived from mannans on yeast cell surfaces are acting effective binder to the bacterial binding sites (Ofek et al., 1977). Pathogens that are mannose-specific Type-1 fimbriae are confused and adsorbed to the MOS, leaving the enterocytes without colonization. In the study of Newman (1994), that had shown that the presence of dietary mannan-oligosaccharides in the intestine had successfully discarded some pathogenic bacteria that had the possibility of attachment to the lumen of the intestine. Mannose was shown by (Oyofo et al., 1989a) to inhibit the *in vitro* attachment of *Salmonella* Typhimurium to intestinal cells of the day old broilers chicken. A study by (Oyofo et al., 1989b) had shown that dietary mannose had a successful effect on inhibiting *Salmonella* Typhimurium in intestinal colonization in broilers. (Spring et al., 2000) had shown an effort in screening different bacterial strains to examine their ability to agglutinate mannan-oligosaccharides in yeast cell preparations (*Saccharomyces cerevisiae*, NCYC 1026). Which showed that the inclusion of MOS in the diet can improve the poultry birds' performance, especially during challenging with *E. coli*, as well as being used as growth promoter antibiotics in poultry industry? A comparison of some attributes with dietary mannan-oligosaccharides and antibiotics is shown in table 1, (Ferket et al., 2002).

**Table 1.** Comparison of some attributes with dietary mannan-oligosaccharides and antibiotics.

| Antibiotics | Mannan-oligosaccharides |
|---|---|
| It reduces the non-specific immunological protection in the mucosa as a result of reducing both beneficial and non-beneficial bacteria (i.e. lactobacilli) | It can increases non-specific mucosal immunological protection by increasing relatively the goblet cell numbers and consequently the mucus secretion and it increases the colonization of beneficial bacteria in the gut. |
| It improves AME and reduces the energy needed for maintenance which consequently improves the net energy availability | It improves net energy available for production by improving dietary AME |
| It improves growth performance parameters under various environmental conditions | Improves growth performance parameters mainly when challenged with enteric pathogens |
| By suppressing enteric microflora it suppresses the competition for the nutrients. | It improves the brush border health so it enhances the absorption process. |
| prolonged or Improper usage can produce antibiotic resistant pathogens | It will not produce bacterial resistance |
| Reduces immunological stress via lowering enteric microbial load | It's important role to stimulate gut-associated system immunity by acting as a non-pathogenic microbial antigen |
| Decreases adverse effects of microflora metabolites by decreasing the microflora | Decreases the adverse effects of microflora metabolites by changing microflora profile |
| It inhibits both the viability and proliferation of some pathogens and beneficial enteric microflora | It acts as a barrier against the attachment and consequent colonization of some enteric bacteria, but it is not bactericidal. |

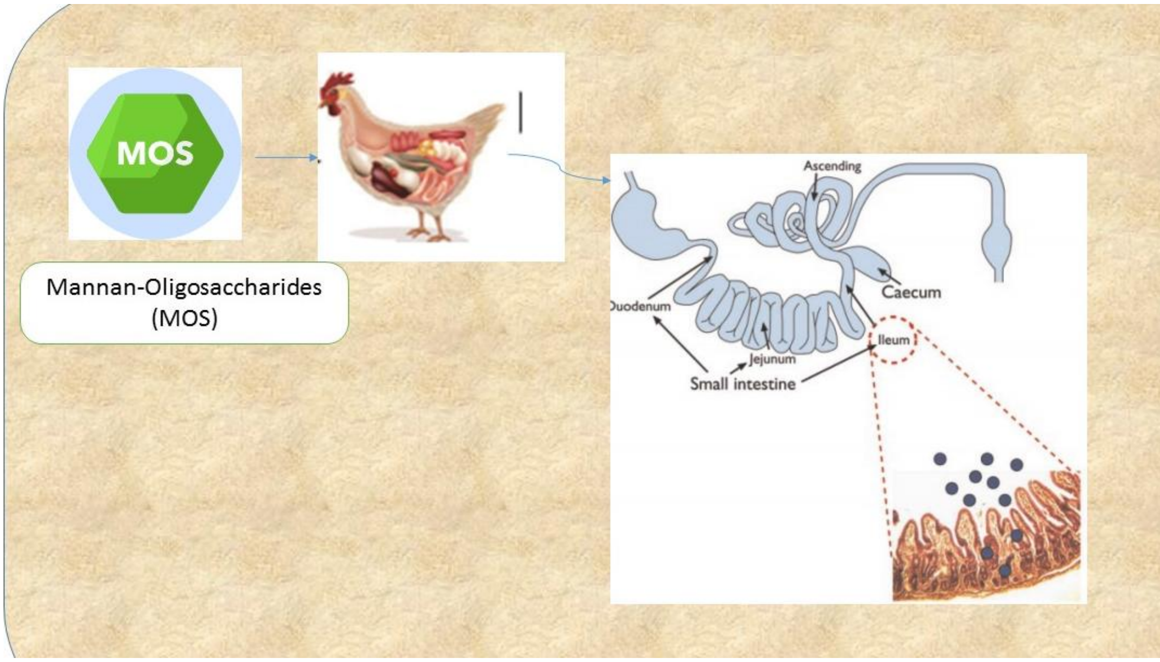


**Figure 2.** A flow diagram illustrating a large surface area is vital for optimal digestive function and nutrient absorption in poultry birds.

## CONCLUSION

After reviewing the compiled literature it can be fully clarified that MOSs can be considered as a potential alternative to antibiotic growth promoters, and even at trace amounts @ 0.1%-0.4% practically usage as commercial feed additive in poultry nutrition would be quite effective in improving the health status and production performance of poultry. Among consumer concerns about danger increasing of antibiotic-resistant pathogens has urged the poultry nutritionist to consider “biologically safer” alternatives. After studying the published literature it is clear now that MOS is considered one of the best alternatives to antibiotic growth promoters. These mannan-oligosaccharides are non-digestible carbohydrates that may have greater benefits than antibiotics if it is used in a synergic way with other non-pharmaceutical enteric conditioners, such as fructo-oligosaccharides, probiotics, bioactive peptides, and some herbs and it would, in this manner, be a helpful additive to reduce feed cost in the poultry industry.

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### Competing interests

Authors declared that they have no conflict of interest.

### Author`s contributions

All the authors significantly contributed to compile and revise this manuscript. MS, MAA, reviewed the literature and initiated the review compilation. MEAEH, ZAB and ME, critically revise the manuscript. FA and MEAEH check the English language accuracy. Finally all authors read and approve the manuscript for publication.

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