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Potential use of tomato pomace as ruminants diet: A review

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To obtain an efficient livestock production, appropriate feeding, health care, and breed selection and development are needed to perform. Feeding is considered to be the most important key factor in enhancing the livestock productivity. Roughage source recently becomes scared, and concentrate feed cost is keeping growing up. Tomato pomace (TP) contains major nutritive values which might be useful. Thus, the aim under this review was to literate on the nutritious value of TP, utilization as feed for Ruminants, and its effect on nutrients intake and apparent digestibility, and ruminal fermentation. The result showed offering diet containing TP significantly increased the nutrients intake and apparent digestibility such as, dry matter, organic matter, and crude protein. The ruminal fermentation was significantly influenced by the diet contained TP, increasing acetic and propionic concentration and also acetic to propionic ratio. The total VFA was also increased by TP. However, ammonia nitrogen was not significant. Growth performance and carcass traits were not significant with TP based diet, except CP and fat composition in carcass. TP supplementation increased milk fat composition and promoted protein yield. The methane emission trended to be significant lower in diet existing TP. From this review, TP could be used as a supplement ingredient for ruminant without adverse effect.

Keywords: Tomato pomace, Ruminant, Digestibility, Nutrient, Ruminal fermentation, Production traits

INTRODUCTION

To obtain an efficient livestock production, appropriate feeding, health care, and breeding selection and development are needed to perform Food and Agriculture Organization (FAO, 2018). Feeding is considered to be the most important key factor in enhancing the livestock productivity; however, inadequate nutrition, scared feed resource, and expensive feedstuffs mainly concentrate feed are the main constraints in agricultural based countries (FAO, 2011; Vasta et al., 2009), and at current time sought more attention and effort to minimize and step up to eliminate these conditions. In ruminant feeding, the diet comes from two main sources, roughage (rice straw, alfalfa, legume, wheat bran etc.) and concentrate (grains, brans, oil seed residues, roots, tubers etc.; FAO, 2018). However, roughage source recently becomes scared, and concentrate feed cost is keeping growing up. Thus, feed additives have been introduced. The introduced feed additives are in both synthesis and natural form. Synthesized feed additives have been utilized widely, but the price is expensive. On the other hand, natural feed additives can be found abundantly from industrial and agricultural sector with low price. The residues or by-products from industry are molasses, dried brewer grain, cottonseed cake and palm kernel meal, and the by-product from agricultural sector are rice straw, corncobs, legume straw, cassava peel and leaf and tomato pomace. These by-products have been widely used in ruminant diet as supplement feed. The residues of tomato from industry, tomato pomace (TP), is the discarded portion from the processing line, and generated a large amount every year (Topal et al., 2006). TP has high moisture content which cause a shortage of storage (Elbadrawy and Sello, 2016) and further pollute the environment if there is no management. The nutritive values of TP have been studied (Mirzaei-Aghsaghali1 et al., 2011). Regarding to the availability of large amount TP and high nutritional values, utilization of TP in Ruminant ration are reviewed. Also nutrient intake, digestibility, characteristic of ruminal fermentation, performance, and production traits responded to diet containing TP of ruminant animal are discussed.

Bioactive compounds in TP

Lycopene and b-carotene were identified as the main carotenoids in lipophilic extracts, with significantly higher content of both compounds in tomato pomace, which also contained significantly higher amount of phenolic compounds (Table 1). This was expected because it is well known that tomato skin is richer in lycopene than toma to pulp; in addition, skin and seeds (major fractions in tomato pomace) have been previously reported to possess significantly higher content of hydrophilic phenolics than pulp (Al-Wandawi et al. 1985; George et al. 2004; Toor and Savage 2005).Lycopene and b-carotene were identified as the main carotenoids in lipophilic extracts, with significantly higher content of both compounds in tomato pomace, which also contained significantly higher amount of phenolic compounds (Table 1). This was expected because it is well known that tomato skin is richer in lycopene than toma to pulp; in addition, skin and seeds (major fractions in tomato pomace) have been previously reported to possess significantly higher content of hydrophilic phenolics than pulp (Al-Wandawi et al. 1985; George et al., 2004; Toor and Savage 2005).Lycopene and b-carotene were identified as the main carotenoids in lipophilic extracts, with significantly higher content of both compounds in tomato pomace, which also contained significantly higher amount of phenolic compounds (Table 1). This was expected because it is well known that tomato skin is richer in lycopene than toma to pulp; in addition, skin and seeds (major fractions in tomato pomace) have been previously reported to possess significantly higher content of hydrophilic phenolics than pulp (Al-Wandawi et al. 1985; George et al., 2004; Toor and Savage 2005).

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Lycopene and beta-carotene are identified as the main carotenoids in lipophilic extracts, with significantly higher content of both compounds in TP, which also contain significantly higher amount of phenolic compounds. This is expected because it is well known that tomato skin is richer in lycopene than tomato pulp; in addition, skin and seeds (major fractions in tomato pomace) have been previously reported to possess significantly higher content of hydrophilic phenolics than pulp (George et al., 2004; Toor and Savage, 2005), as more than 85% lycopene of total intake could obtain from both fresh tomato and tomato processed products via consumption (Amiri-Rigi and Abbasi, 2016). About 5 to 30% of TP were generated from tomato industry; in which some were used as feed supplementation and remaining was disposed in land. Seed (33%), skin (27%), and pulp (40%) represented in fresh TP while seed (44%) and skin and pulp (56%) represented in dry form (Poojary and Passamonti, 2015), in addition lycopene presented at high amount in skin (Choudhari and Ananthanarayan, 2007) which was more than five-folds compared to pulp portion (Papaioannou and Karabelas, 2012). Lycopene and other derivatives of carotenoid extraction from TP have been worked out (Strati and Oreopoulou, 2014).Other compounds including polyphenols and tocopherols also deposited abundantly in TP (Kalogeropoulos et al., 2012; **Table 1**).

Table 1 Phenolic compound, flavonoids, lycopene and beta-carotene found in tomato pomace (TP)

Components	TP
Total phenolics (mg GAE kg^{-1})	1229.5
Total flavonoids (mg QE kg^{-1})	415.3
Lycopene (mg kg^{-1})	510.6
beta-carotene (mg kg^{-1})	95.6

Source: Violeta et al., 2018

Chemical composition of TP

Tomato is an edible food that can be

consumed fresh and processed form. The processed form is divided into three group: 1) preserved tomato such as tomato juice, tomato paste; 2) dried tomato, like tomato powder, dried tomato fruit; and 3) based tomato as food, such as tomato soup, tomato ketchup (Heuvelink, 2005). Beside of the processing line, there are a lot of residues or by-products have been generated or produced, called TP. TP including peel, seed and pulp can be sun-dried or oven-dried and sold to livestock raisers as feed. Seed is a source of good protein and peel is rich in fiber (Gould, 1992). The chemical composition of TP is being in range of 14.2% to 96.3% dry mater, 87.8% to 96.2% organic matter, 15.3% to 26.4% crude protein, 3.98% to 15.9% ether extract (fat), 13.9% to 50.7% acid detergent fiber, 19.1% to 63.6% neutral detergent fiber, 26.3% to 48.7% acid detergent lignin, 2.75% to 3% ash, and 38.01% cellulose and 31.42% hemicellulose. In **Table 2** presented the chemical composition of TP (average, %DM).

TP used as animal feed

Tomato by-product, tomato pomace (TP), is the residues from the processing line for paste, ketchup, juice, sauce, and puree product including pulp, seed and skin, in which peel and seed account for from 20% to 50% of the initial weight (Cassinerio et al., 2015). In 2016, tomatoes of 177MT were planted globally which equal to 30% of production (Rudolf, 2018), in which 10% to 40% TP remain after processed into different products (Topal et al., 2006). The increasing of production and residue or by-product from agro-industry concern the environment, such as TP (Sogi et al., 2005; King and Zeidler, 2004; Fahimdanesh and Bahrami, 2013). Although, TP is considered as a factor concerning the environment, it has been gained more attention by animal nutritionist by using as livestock feed to reduce the cost of conventional feed mainly grains and environment impact (Kasapidou et al., 2015; Mirzaei-Aghsaghali et al., 2011). Utilization of TP as feedstuff for both non-ruminant and ruminant animal has been reported. Soto et al., (2015) studied on barley grain diet replacement with tomato waste and cucumber effect on characterization of rumen fermentation and microbial community in goats, and the result showed that up to 250g kg^{-1} of tomato waste could replace barley grain diet. Previously, Valenti et al., (2018) supplemented dried tomato pomace in lamb diet showed reduced commercial concentrate ration without negative effect on performance and meat quality of animal; and Yuangklang et al., (2010) demonstrated a decreased feed intake causing a reduction in growth of beef cattle fed dried tomato pomace. Cassinerio et al. (2015) used tomato seeds replaced whole cottonseed in lactating cow diet resulting without altering production.

Dietary containing TP effect on nutrients intake and digestibility

Using *in sacco* and *in vitro* technique, Ventura et al., (2009) had conducted a research to measure organic matter and crude protein digestibility of tomato fruit and plant by-product with permanent rumen cannula of goat. The result showed higher *in sacco* organic matter degradation and *in vitro* organic matter digestibility were found in tomato fruit than tomato plant by-product. And also the effective of *in sacco* organic matter degradation was higher in tomato fruit than tomato plant by-product; however, *in sacco* crude protein degradation effectiveness was low in tomato fruit by-product. The low crude protein degradation was due to the high protein lignification, half of protein in tomato linked to ADFom (Ventura et al., 2009. Arco-Perez et al., (2017) conducted a study in dairy goat fed diet containing tomato by-products silage, the result showed significantly different in fat digestibility and dry matter intake was not significant. This result is in an agreement with Molina-Alcaide et al. (2010) and Romero-Huelva et al., (2012) who found non-significant in dry matter intake of dairy goat fed feed block containing tomato waste. In Romero-Huelva et al., (2012)'s study, found decreasing in apparent digestibility of dry matter, organic matter and fat in goat after feeding diet containing tomato pomace(**Table 3**).The decreasing of apparent digestibility of dry matter, organic matter and fat was due to the lower of concentrate level in diet replaced partially with tomato waste based feed block, Romero-Huelva et al. reported and also agreed to the report of Ben Salem and Znaidi (2008).In beef cattle, feeding diet containing dried tomato pomace reduced feed intake (Yuangklang et al., 2010). Decreasing of feed intake represent the depression of beef cattle growth after feeding diet containing dried tomato pomace.

Table 2 The chemical compositions of TP used in ruminants feed

Chemical compositions	Tomato pomace
Dry matter, %	67.89
Organic matter, % DM	92.48
Crude protein, % DM	20.26
Ether extract, % DM	10.88
Acid detergent fiber, % DM	37.4
Neutral detergent fiber, % DM	49.68
Acid detergent lignin, % DM	37.52
Ash, % DM	3.05
Cellulose, % DM	38.01
Hemicellulose, % DM	31.42

Sources: (Soto et al., 2015; Denek and Can, 2006; Abdollahzadeh et al., 2010; Abbeddou et al., 2015; Mirzaei-Aghsaghali et al., 2011; Valenti et al., 2018; Kheiralla et al., 2018; Aghajanzadeh-Golshani et al., 2010; Razzaghi et al., 2015)

Table 3 Responding of nutrient intake and apparent digestibility in goat fed diet containing tomato pomace

Item	Diet		SEM	P value
	Control	TP[1]		
Intake (g/day)				
Total DM	639	651	31.2	0.60
Alfalfa hay	316	309	21.6	0.84
Concentrate	323[b]	156[a]	11.7	<0.001
Block	0[a]	185[d]	5.81	<0.001
OM	578	570	27.8	0.50
Fat	11.6[b]	7.97[a]	0.52	0.001
CP	106	103	5.44	0.06
NDF	305	328	15.9	0.68
ADF	174	197	9.10	0.68
Apparent digestibility (%)				
DM	67.8[b]	62.2[a]	0.30	0.02
OM	71.1[b]	65.8[a]	0.26	0.02
Fat	67.5[b]	58.3[a]	1.36	0.05
CP	72.4	70.3	0.50	0.80
NDF	58.8	59.5	0.62	0.94
ADF	55.6	54.9	0.70	0.92

[1] Alfalfa hay (25.6 g/kg $BW^{0.75}\cdot d^{-1}$), concentrate (12.8 g/kg $BW^{0.75}\cdot d^{-1}$), and feed blocks including tomato pomace (TP; 15.5 g/kg $BW^{0.75}\cdot d^{-1}$), TP= tomato pomace, SEM= standard error of mean, DM= dry matter, OM= organic matter, CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber
Source: Romero-Huelva et al. (2012)

Furthermore, the percentage of feed intake of body weight also decreased with ration containing dried tomato pomace. This mean that decreasing of feed intake was not the reason of lowering body weight, but it was the cause of tomato pomace addition. In Holstein dairy cow study, feeding ensiled mix tomato and apple pomace increased ($p<0.05$) dry matter and organic matter digestibility (Abdollahzadeh et al., 2010). This finding has been supported by a few studies (Ojeda and Torre, 2001), that tomato pomace could improve the quality of diet. Increasing digestibility of dry matter and organic matter in diet containing ensiled mixture of tomato and apple pomace might be the presence of pectin and high soluble carbohydrate (NRC, 2001; Del Valle et al., 2006; Cherdthong et al., 2016). Kefyalew et al., (2015) studied in Hararghe highland sheep fed dried tomato pomace as supplement in concentrate and hay diet. Under this study, supplemented dried tomato pomace significantly influenced the intake of total dry matter and organic matter. Supplemented dried tomato pomace reduced the intake of hay dry matter; however, it increased the intake of total dry matter and organic matter compared to the un-supplemented diet. The study found higher in dry matter intake, organic matter and crude protein intake with dried tomato pomace supplementation. The higher of dry matter intake might be due to the appreciation of dried tomato pomace in increasing the nutritive value of diet and crude protein intake. On the other hand, lower in dry matter intake in non-supplement diet was due to the low quality of diet and its significant lower in crude protein intake (Kefyalew et a., 2015), and also similarly reported by Bekele et al. (2013). Supplementing of dried tomato pomace in hay diet failed to improve the digestibility of dry matter and organic matter, but these were improved when supplemented in concentrate mix. The digestibility of crude protein was increased with dried tomato pomace supplementation. The lower in dry matter and organic matter digestibility in hay diet supplement dried tomato pomace was due to the higher fiber content in the supplement ingredient that might influence the dry matter digestibility as also reported by Checke (1999). The higher in crude protein digestibility could be explained by the high crude protein content in dried tomato pomace which agreed to the result of Ferrell et al., (1999).

Dietary containing TP and rumen fermentation

The rumen fermentation of goat did not influenced by tomato waste and/or cucumber waste utilization (Soto et al., 2015). These authors found that increased tomato waste and tomato plus cucumber mixture concentration, increased the end pH of incubation and gas production; however, ammonia nitrogen, substrate degradation, and total VFA were not significant. This finding is in an agreement with Abdollahzadeh et al., (2010). Abdollahzadeh and their co-workers conducted a research in Holstein dairy cow, and the result showed that the ruminal pH and VFA concentration was significantly affected by ensilaged mixed tomato and apple pomace, and ammonia nitrogen did not response to the supplement. After 3h of feeding, the ruminal pH significantly decreased with increasing of ensilaged mixture tomato and apple pomace amount (0% to 30% EMTAP). The VFA production, acetic, propionic, acetic:propionic ratio and total VFA, are high in trend, which agreed to the finding of Chumpawadee and Pimpa (2009), studied effect of fibrous source including tomato pomace in beef cattle. Explaining to the change of ruminal pH and VFA production, a few reasons has been traced. Abdollahzadeh et al., (2010) left an assumption that the change of VFA production was due to the rate and extent of carbohydrate degradation. Moreover, decreasing of ruminal pH was due to the acidity of ensiled mixture of tomato and apple pomace (pH: 3.5), especially contained malic and citric acid (NRC, 2001). In steer and fistulated steer study, Yuangklang et al., (2010) found that increased in blood urea concentration and decreased ruminal fermentation after feeding ration containing dried tomato pomace. Furthermore, these authors also found an increase in ruminal ammonia. Regarding to this, the authors made an assumption that an increased blood urea was caused by the increasing of ruminal ammonia. This relationship was also reported by Gressley and Armentano (2007). In addition, increasing of ruminal ammonia links to the depressing of bacterial growth and less microbial protein synthesis after fed ration containing dried tomato pomace (Yuangklang et al., 2010). Similarly, Yuangklang et al. (2010) also found that feeding diet containing dried tomato pomace in the acidity of the rumen host. The authors addressed the reasons that it was due to the decreasing in rumen fermentation when ingested dried tomato pomace, which reduced the passage rate of diet through the rumen. In goat fed diet containing tomato and cucumber waste study, Romero-Huelva and Molina-Alcaide (2012) found that feed block containing tomato waste against methanogen bacteria and increased total

VFA concentration, but ammonia nitrogen, acetate concentration, and ruminal pH were similar; in which some results were contrasted to Arco-Perez et al., (2017; **Table 4**). Deeply, goat fed feed block containing tomato waste significantly reduced methane emission, butyrate, and acetate:propionate ratio; however, propionate concentration significantly increased in diet containing tomato waste.

Table 4 Responding of ruminal fermentation in dairy goat fed ration containing tomato pomace

Item	Diet		SEM	P value
	Control	TSD[1]		
pH	7.07	7.33	0.13	0.16
Total VFA (mmol/l)	77.2	56.6	6.92	0.45
mol/100mol				
Acetate	67.0[a]	63.0[b]	0.36	0.005
Propionate	12.7	13.6	0.53	0.52
Butyrate	14.2[b]	16.0[a]	0.34	0.02
Acetate/Propionate	5.27	4.63	0.23	0.41
Methane emission				
Methane (l/day)	20.1	24.1	2.88	0.65
Methane (l/kg DMI)	21.9	18.7	0.79	0.08
Microbial densities (gene copies/g fresh matter				
Total bacteria	11.7	11.8	0.25	0.31
Methanogens	9.13	9.15	0.45	0.99
Protozoa	7.50	7.99	0.49	0.05

[1] TSD = tomato surplus silage diet, VFA= volatile fatty acid, DMI= dry matter intake

Source: Arco-Perez et al., (2017)

Table 5 Growth performance of beef steer fed diet containing tomato pomace

Study	Level (%)	Investigated growth performance (kg)				Source
		Initial BW	Final BW	ADG	FCR	
Added TP in concentrate	0	153.25	230.55	0.65	5.28	Kusanteay and Uriyapongson (2016)
	15	154.5	239.4	0.71	4.91	
	30	146.25	233.25	0.73	4.48	
	45	152.5	219.28	0.56	5.61	
	SEM	9.62	16.12	0.07	0.34	
	L	NS	NS	NS	NS	
Replaced soybean meal by TP	0	256.8	381.3[a]	1.03	13.75	Yuangklang et al. (2010)
	3.2	258.8	372.0[b]	0.94	14.39	
	8	258.5	367.0[b]	0.9	14.2	
	11.2	260.3	366.0[b]	0.88	14.37	
	SEM	1.74	0.97	13.9	0.47	
	L	NS	*	NS	NS	

TP= tomato pomace, SEM= standard error of mean, L= linear of contrast effect, NS= non-significant, *= significant, BW= body weight, ADG= average daily gain, FCR= feed conversion ratio, [ab] means with different superscript letter within column differed significantly ($p<0.05$)

The authors have raised up a few reasons on an unchanged of ruminal pH that was due to the lack of relationship between pH and total VFA which was agreed with the report of Busquet et al., (2005) and Cantalapiedra-Hijar et al., (2009), and also the concentrate level with the buffer properties of alfalfa which could result without any change of ruminal pH (Zebeli et al., 2008). Reducing of butyrate concentration could be explained by the positive relationship of butyrate concentration and diet containing various levels of nonstructural carbohydrate which could be beneficial to bacteria producing butyrate (Carro and Ranilla, 2003). Reduction of methane emission is a very interesting result, lower greenhouse. The reasons of methane emission reduction could be explained as: 1) less fermentation of organic matter in the rumen, but organic matter fermentation increased at intestine avoiding available hydrogen for methane production and decreasing methanogen bacteria activity (Ben Salem and Znaidi, 2010; Martin et al., 2010), and 2) feed block containing tomato waste contains phenolic compounds and/or plant secondary compounds that could inhibit the methanogenic activity as also suggested by Patra and Saxena (2010) and Cherdthong et al. (2018, 2019).

Dietary containing TP effect on growth performance, carcass characteristics and milk production

According to Kusanteay and Uriyapongson (2016) studied on various levels of TP effect on feed intake and growth performance of Thai native cattle. Increasing levels of TP had no effect on feed intake, final weight, and weight gain and feed conversion ratio (**Table 5**). However, total feed intake decreased as levels of TP increased, which could be due to the high fiber content in TP. The result was in an agreement with Romero-Huelva and Molina-Alcaide (2012), who found reducing in alfalfa hay intake when replaced with TP based feed block. Yuangklang et al. (2010) fed steers with diet containing TP, the result indicated that final body weight (**Table 5**), feed intake, and blood urea nitrogen were significantly influenced by TP addition; however, average daily gain and feed conversion ration were similar among treatments. TP addition in rations reduced significantly on final body weight and feed intake, but blood urea nitrogen was increased. Increasing blood urea nitrogen was caused by the increasing of ruminal ammonia nitrogen after feeding TP (Yuangklang et al., 2010), and increasing ruminal ammonia nitrogen could be explained by the low microbial protein synthesis and would also depressed the growth of ruminal living organism. In addition, reducing in final body weight could be due to the variation of diet, increasing levels of TP accompanied by urea and decreasing amount of cassava chip and soybean meal. It means the change of final body weight was mainly caused by the variation of soybean meal, cassava chip and urea concentration rather than TP change. Similar result, body weight change, was also reported by Abbeddou et al. (2015), who found significantly decreasing in body weight when fed diet containing 30% of TP. Valenti et al., (2018) studied in lambs supplement TP, decreased growth performance of lambs (**Table 6**). Growing Markhoz goat fed different levels of TP as protein supplement showed have no effect on carcass characteristics of goat including empty body weight, hot carcass weight, dressing percentage and carcass length; however, inclusion levels of TP significantly influenced the carcass chemical composition (**Table 7**; Farzad, 2012). However, Taasoli and Kafilzadeh (2008) studied in finishing lambs fed pomace from apple, result showed live body weight, hot carcass weight, cold carcass weight and carcass without fat tail were highly significantly affected by apple pomace diet. In finishing steers, Zhou et al. (2014) demonstrated in contrast to Taasoli and Kafilzadeh, but in an agreement with Farzad (2012), which found no significant in carcass characteristics when received with ensiled mulberry leaves or sun dried mulberry leaves pomace. Milk yield (g/day) of ewes including total energy collected milk (ECM), change in ECM, and protein was significantly influenced by TP supplement, except fat. Milk composition such as, solid not fat, fat, protein and lactose were also significant (**Table 8**; Abbeddou et al., 2015). Supplemented TP in ewes' diet significantly decreased milk yield and milk composition. However, Ebeid et al., (2015) found significantly only in fat corrected milk and fat composition in dairy buffaloes fed ration containing TP silage (**Table 9**). These authors found in increasing of fat composition, this could be due to the increasing of acetate production, promoting more milk fat synthesis. The result of Abbeddou et al. (2015) was in an agreement with their previous work in 2011 and 2014 and Romero-Huelva et al., (2012). On other hand, Shdaifat et al., (2013) studied in diet containing TP ration fed Awassi ewes, found no effect on milk yield and composition, and Romero-Huelva et al. (2012) was also reported similarly.

CONCLUSION

According to the chemical composition of TP, it is a potential supplement ingredient to low quality diet. It can be used to replace as protein and fibrous source, and it in addition, is a good source of carotenoid and phenolic compounds. Under this review, dietary supplement TP improved nutritive value of the diet by increasing of dry matter and organic matter intake and also nutrients digestibility. Supplement TP caused lower in ruminal pH, but did not change the ammonia nitrogen. The total VFA production was improved with tomato pomace supplementation. TP supplementation promoted CP content in the carcass and increased milk fat composition. Growth performance was not changed by diet containing TP. The methane emission trend to be significant while protozoa density was significant with diet containing TP. For dairy cattle, TP should be added at an appropriate amount in feed. TP should be added less than 20% in the diet.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

The authors shared and made a contribution of all information to every part of this work. The final version of this work was read and approved by authors.

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