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Camel milk and its fermented products as a source of potential probiotic strains and novel food cultures: a mini review

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Abstract: Application of probiotic bacteria in dairy products is a promising way to improve the intestinal microflora balance. A number of lactic acid bacteria (LAB) have been isolated and identified as probiotics from cow and goat milk and its products. Camel milk is considered as health promoting and being consumed widely as a part of the staple diet in parts of Africa and Asia. LAB in camel milk may be a potential source of probiotics to be used in dairy technology. There is a trend towards new and novel probiotic strains where camel milk and its products could be a basic search for unique probiotic-type functional foods. Therefore, the objective of this study is focusing on review some previous studies on isolation and identification of potential probiotic strains and novel food cultures from raw camel milk and its products.
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Keywords*:* probiotics, camel milk, biological properties.

Introduction

Probiotics are live microorganisms that when present in sufficient amounts in the digestive tract may confer health benefits on the host (Lourens-Hattingh and Viljoen, 2001). Combination of starter culture and probiotics (Bifidobacterium, Lactobacillus) is widely used in fermented foods such as dairy products (Lourens-Hattingh and Viljoen, 2001; Vinderola et al., 2000).

A number of LAB have been classified as potential probiotics. One of the main requirements in dairy food manufacture is the appropriate selection and stability of probiotics for desirable texture and flavor. In addition, quality assurance criteria for potential probiotics should be characterized such as the ability to survive during passage through the gastrointestinal tract, including low pH, bile salt concentrations and digestive enzymes, high survival rate (minimum 10^6-10^7 CFU/g) (Hosseini et al., 2009). The initial microbiological quality of raw milk affects the final dairy products (Ritcher and Vadamuthu, 2001). Isolation and identification (*in vitro* studies) of lactic acid bacteria with probiotic potential from cow and goat milk and their products have been well studied (Guessas et al., 2005; Mezaini et al., 2009). However, there are insufficient *in vivo* studies on these probiotics isolated from cow and goat milk to confirm any beneficial health effects. There is a trend towards new and novel probiotic strains (Olnood et al., 2016) where camel milk and its products could be a basic search for unique probiotic-type functional foods.

Camel milk besides being part of the staple diet in parts of Africa and Asia, is also considered as health promoting (Benmechernene et al., 2013). It is common practice in these regions to recommend consumption of camel milk either in fresh or sour state (Abdelgadir et al., 2008) for controlling diabetes and its complications such as high cholesterol levels, liver and kidney disease, decreased oxidative stress and delayed wound healing (Shori, 2015). Camel milk and its fermented products did not receive enough attention and few studies have been carried out on the isolation and characterization of potential probiotic strains (*in vitro*) from camel milk (Abbas and Mahasneh, 2014; Benmechernene et al., 2013; Hamed and Elattar, 2013; Madhu et al., 2012; Maurad and Meriem, 2008; Yateem et al., 2008). Therefore, the objective of this study is focusing on review some previous studies on isolation and identification of potential probiotic strains and novel food cultures from raw camel milk and its products.

Isolation and identification of probiotics and and novel food cultures from camel milk:

Raw camel milk and its fermented products can be good sources of potential probiotic strains. The mixture of different species of bacteria e.g. *Lactobacillus fermentum*, *Lactobacillus plantarum*, *Lactobacillus casei*, *Lactococcus lactis* subsp. *lactis*, *Enterococcus* *faecium*, and *Streptococcus thermophilus* (Table 1) has been recognized as the predominant dairy bacteria. A numbers of LAB have been classified as probiotics. Strains of Lactobacillus, Bifidobacterium and Enterococcus (Ogier and Serror, 2008; Yateem et al., 2008) are the most commonly used as probiotic bacteria. Maurad & Meriem, (2008) have isolated two *Lactobacillus plantarum* strains (SH12 and SH24) from traditional butter made from camel milk (shmen) as starter cultures for camel milk fermentation. These two strains showed rapid acidification activity, good proteolytic activity, antibacterial activity and high survival rate after freeze-drying. A previous study reported that LAB distribution of raw camel milk in Morocco had a high variety of dominated species such as *Lactococcus lactis* subsp. *lactis* (17.5%), *Lactobacillus helveticus* (10%), *Streptococcus salivarius* subsp. *thermophilus* (9.20%), *Lactobacillus casei* subsp. *casei* (5.80%) and *Lactobacillus plantarum* (5%) (Khedid et al., 2009). A bacterial strain Enterococcus hirae (MTCC 10507) was isolated from camel milk by Madhu et al., (2012). They found that *E. hirae* showed significant lipase activity of 2000 U/ml at pH 7.2-7.5 and temperature 30 °C - 40°C.

Several isolation of LAB from raw camel milk collected from Arabian camels in Egypt have been identified as *Enterococcus faecium* (seven isolates), *Enterococcus durans* (one isolate), *Aerococcus viridians* (one isolate), *Lactococcus lactis* (one isolate) and *Lactobacillus plantarum* (one isolate) (Hamed and Elattar, 2013). All these bacteria demonstrated the potential probiotic ability such as effectiveness against pathogens (*Salmonella typhi* ATCC 14028, *Escherichia coli* ATCC 25922 and *Vibrio fluvialis*), resistance to stomach acid (pH 3.0), tolerance against 0.3% bile salts and none of the isolates caused blood hemolysis (Hamed and Elattar, 2013). Furthermore, Benmechernene et al., (2013) have isolated two strains of *Leuconostoc mesenteroides subspecies mesenteroides* (B7 and Z8) from Algerian camel milk. The two strains showed high potential probiotic profile *in vitro* such as good survival at low pH (2-3 and 4) in the presence of 0.5%, 1%, and 2% of bile salts and at pH 3 in the presence of 3mg/mL pepsin (Benmechernene et al., 2013). In addition, both strains had antimicrobial activity against pathogenic e.g. *Listeria innocua*, *Listeria ivanovii* and *Staphylococcus aureus*.

Thirty four isolates from fresh and fermented camel milk from Jordan have been identified as *Lactobacillus paracasei* ssp *paracasei* (41%), *Lactobacillus plantarum* (23%), *Lactobacillus rhamnosus* (18%), *Lactobacillus fermentum* (12%) and *Lactobacillus brevis* (6%) with highly potential probiotics properties *in vitro* (Abbas and Mahasneh, 2014). *Lactobacillus amylophilus* has been also isolated from camel milk (Khedid et al., 2009). This strain was proven to be beneficial in direct fermentation of crude starch to lactic acid and has a lot of applications in food industries (Naveena et al., 2004). *Lactococcus raffinolactis* is isolated from raw camel milk and also fermented camel milk (Suusac) by Khedid et al., (2009) and Lore et al., (2005) respectively. Despite is present as nonstarter culture in raw milk, little is known about this species and its role in dairy foods. Some *Weissella* spp such as *W. confuse* has been isolated from fermented camel milk. This bacterium is found in fermented foods and has been suggested as a potential probiotic (Lee et al., 2012). Another species of *Weissella* have been isolated from Shubat (*Weissella helleca*, Table 1). To the best of our knowledge no studies have found on *Weissella helleca* as probiotics or the potential health risks for consumers. *Aerococcus viridans* isolated from raw camel milk (Table 1) is known to be used as starter culture for controlled fermentation (Ajayi, 2011). However, very few studies have done on the effect of *Aerococcus viridans* as potential probiotic bacteria and their applications in the dairy industry.

Conclusion

Nowadays to satisfy dairy industry and consumer need to find new probiotics with beneficial health effects, Lactic acid bacteria from camel milk possess a potential source of biological benefits to be used in dairy technology. Despite LAB from cow milk have widely studied, yet, few studies have been done on the camel milk to study their potential probiotics properties. More extensive studies are needed for new starter and probiotic strains of LAB isolation, identification and characterization from raw and fermented camel milk products for possible use as industrial cultures in the manufacture of fermented camel milk products. In addition, further research on molecular characterization of some available isolation from camel milk and its products are recommended. In addition, some identified LAB strains isolated from camel milk need further studies to demonstrate their safety, functional and technological properties, antimicrobial activities against pathogens and survival ability in human gastrointestinal tract.

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Table 1. Isolation and identification of potential probiotic strains and novel food cultures from camel milk and its fermented products.

Species	Sample type/ source	pH	Media	Incubation condition	Temperature	Duration (h)	Number (%b) of isolates obtained from media	References
Enterococcus casseliflavus / Enterococcus gallinarum	Milk container surface samples (n=8)	ND	MRS	Anaerobically	37°C	48	2 (25.0%)	(Jans et al., 2012)
Enterococcus casseliflavus	Raw milk (n=30)	ND	M17	Aerobically	45°C	48	9 (7.5%)	(Khedid et al., 2009)
Enterococcus faecalis	Pooled milk	6.5 ± 0.1	M17	Aerobically	30°C	24	2 (11.8%)	
	(n = 5)		M17	Aerobically			1 (50.0%)	(Jans et al., 2012)
	Local collection		KFS	Aerobically	30°C	24	3 (50.0%)	
	point (n = 5)	6.4 ± 0.2			43 °C	48		
	Final market		KFS	Aerobically	43 °C	48	6 (100.0%)	
	(n = 4)	6.2 ± 0						
	Milk container		KFS	Aerobically	43 °C	48	6 (60.0%)	
	surface samples	ND				24		
	(n=8)		M17	Aerobically	30°C	48	1 (1.0%)	
	Suusac (n = 24)	4.9 ±0.9	KFS	Aerobically	43 °C		3 (2.2%)	
	Raw milk (n=30)	ND	M17	Aerobically	45°C	48	4 (3.3)	(Khedid et al., 2009)
	Shubat (n=7)	3.7-4.1	MRS	Aerobically	37°C	48	3(5%)	(Rahman et al., 2009)
Enterococcus faecium	Gariss (n=9)	3.79-4.43	MRS	Anaerobically	37°C	48	5(7-36%)	(Abdelgadir et al., 2008)
	Shubat (n=7)	3.7-4.1	MRS	Aerobically	37°C	48	5(14%)	(Rahman et al., 2009)
Enterococcus durans	Raw milk (n=21)	ND	MRS	Anaerobically	37°C	48	1 (9%)	(Hamed and Elattar, 2013)

Lactobacillus spp.	Suusac (n = 24)	4.9 ± 0.9	MRS	Anaerobically	37°C	48	1 (0.7%)	(Jans et al., 2012)
	Raw milk (n=30)	ND	MRS	Aerobically	30°C	24–48	7 (5.8%)	(Khedid et al., 2009)
Lactobacillus casei subsp. *casei*	Gariss (n=24)	3.41-3.82	MRS	n	n	n	4(3-7%)	(Hassan et al., 2008)
Lactbacillus casei	Raw milk (n=30)	ND	MRS	Aerobically	30°C	24–48	1 (0.8%)	(Khedid et al., 2009)
Lactobacillus casei subsp. *rhamnosus*	Raw milk (n=30)	ND	MRS	Aerobically	30°C	24–48	6 (5%)	(Khedid et al., 2009)
Lactobacillus plantarum	Raw milk (n=21)	ND	MRS	Anaerobically	37°C	48	1 (9%)	(Hamed and Elattar, 2013)
	Suusac (n=15)	3.6 -4.4	MRS	Anaerobically	30°C	72	n(16%)	(Lore et al., 2005)
	Gariss (n=12)	ND	MRS	Anaerobically	30°C	72	n(29.17%)	(Ashmaig et al., 2009)
	Gariss (n=24)	3.41-3.82	MRS	n	n	n	8(3- 35%)	(Hassan et al., 2008)
	Suusac (n = 24)	4.9 ± 0.9	MRS	Anaerobically	37°C	48	4 (2.9%)	(Jans et al., 2012)
Lactobacillus fermentum	Gariss (n=9)	3.79-4.43	MRS	Anaerobically	37°C	48	9(23-89%)	(Abdelgadir et al., 2008)
	Gariss (n=24)	3.41-3.8	MRS	n	n	n	3(2-7%)	(Hassan et al., 2008)
	Gariss (n=12)	ND	MRS	Anaerobically	30°C	72	n(4.17%)	(Ashmaig et al., 2009)

Lactbacillus								
helveticus								
		3.79-						
		4.43						
	Gariss (n=9)							(Abdelgadir et al., 2008)
				Anaerobically	37°C			
			MRS					
								(Rahman et al., 2009)
					37°C		1(9%)	
						48		
								(Khedid et al., 2009)
		3.7-4.1		Aerobically	45 °C		5(13%)	
Lactbacillus	Shubat (n=7)		MRS			48		(Jans et al., 2012)
					37°C			
brevis			MRS					
		ND		Aerobically			12 (10%)	
						24-48		
							12 (8.6%)	
	Raw milk (n=30)					48		
		4.9 ± 0.9						
			MRS					
				Anaerobically				
	Suusac (n =24)							(Hassan et al., 2008)
					n			
Lactobacillus						n		(Khedid et al., 2009)
							4(1-21%)	
paracasei								(Ashmaig et al., 2009)
		3.41-						
subsp. *tolerans*			MRS			24–48		
		3.82		n			4 (3.3%)	
Lactbacillus	Gariss (n=24)					72		(Rahman et al., 2009)
					30°C		n(8.33%)	
paracasei			MRS					
		ND		Aerobically				
Lactbacillus	Raw milk (n=30)		MRS			48		(Khedid et al., 2009)
		ND		Anaerobically	30°C		3(5%)	
amylophilus	Gariss (n=12)							
Lactobacillus			MRS			24–48		(Ashmaig et al., 2009)
		3.7-4.1		Aerobically	37°C		2 (1.7%)	
Curvatus	Shubat (n=7)							(Khedid et al., 2009)
Lactbacillus	Raw milk (n=30)		MRS			72		
		ND		Aerobically	30°C		n (8.33%)	
salivarius						24–48		
							2 (1.7%)	
Lactbacillus	Gariss (n=12)		MRS					
		ND		Anaerobically	30°C			
leichmanii			MRS			72		(Lore et al., 2005)
		ND		Aerobically	30°C		n	
Lactbacillus	Raw milk (n=30)							
acidophilus	Suusac (n=15)		MRS			72		
		3.6 -4.4		Anaerobically	30°C		n	
Lactbacillus						n		
							4(1-21%)	
animalis	Suusac (n=15)		MRS					
		3.6 -4.4		Anaerobically	30°C			
Lactbacillus	Gariss (n=24)		MRS			n		(Lore et al., 2005)
		3.41-		n	n		1(0-7%)	
divergens						72		(Hassan et al., 2008)
		3.82					n(4.17%)	
Lactbacillus	Gariss (n=24)		MRS					
				n	n			
rhamnosus	Gariss (n=12)		MRS			72		(Hassan et al., 2008)
		3.41-		Anaerobically	30°C		n(4.17%)	
Lactbacillus						72		(Ashmaig et al., 2009)
		3.82					n(4.17%)	
gasseri	Gariss (n=12)		MRS					
		ND		Anaerobically	30°C			
Lactbacillus	Gariss (n=12)		MRS			72		(Ashmaig et al., 2009)
				Anaerobically	30°C		n(4.17%)	
raffinolactis						72		(Ashmaig et al., 2009)
		ND					n(25.00%)	
Lactbacillus	Gariss (n=12)		MRS					
		ND		Anaerobically	30°C			
alimentarium	Gariss (n=12)		MRS			72		(Ashmaig et al., 2009)
				Anaerobically	30°C		n(4.17%)	
Lactbacillus								(Ashmaig et al., 2009)
		ND						
sakei	Gariss (n=12)		MRS			48		
		ND		Anaerobically	30°C		6(26%)	
								(Ashmaig et al., 2009)
	Shubat (n=7)		MRS			24–48		
		ND		Aerobically	37°C		5 (4.2%)	
Lactobacillus								(Rahman et al., 2009)

Lactococcus lactis subsp. *cremoris*	Raw milk (n=21)	ND	MRS	Anaerobically	37°C	48	1(9%)	(Hamed and Elattar, 2013)
	Raw milk (n=30)	ND	Elliker	Aerobically	30°C	48	2(1.7%)	(Khedid et al., 2009)
Lactococcus lactis subsp. *lactis*	Local collection point (n = 5)	6.4 ± 0.2	MRS	Anaerobically	37°C	48	1 (5.6%)	(Jans et al., 2012)
	Final market (n = 4)	6.2 ± 0	MRS	Anaerobically	37°C	48	1 (3.3%)	
	Milk container surface samples (n=8)	ND	MRS	Anaerobically	37°C	48	1 (12.5%)	
	Suusac (n =24)	4.9 ± 0.9	MRS M17	Anaerobically Aerobically	37°C 30°C	48 24	9 (6.5%) 23 (22.3%)	
	Raw milk (n=30)	ND		Aerobically	30°C	48	21 (17.5%)	(Khedid et al., 2009)
Lactococcus. garviae	Raw milk (n=30)	ND	Ellike Elliker	Aerobically	30°C	48	4 (3.3%)	(Khedid et al., 2009)
Lactococcus lactis biovar. diacetylactis	Raw milk (n=30)	ND	Elliker	Aerobically	30°C	48	2 (1.7%)	(Khedid et al., 2009)
Lactococcus raffinolactis	Raw milk (n=30)	ND	Elliker	Aerobically	30°C	48	2 (1.7%)	(Khedid et al., 2009)
	Suusac (n=15)	3.6 -4.4	MRS	Anaerobically	30°C	72	n	(Lore et al., 2005)
Leuconostoc spp.	Milk container surface samples (n=8)	ND	MRS	Anaerobically	37°C	48	5 (62.5%)	(Jans et al., 2012)
	Suusac (n = 24)	4.9 ± 0.9	MRS M17	Anaerobically Aerobically	37°C 30°C	48 24	5 (3.6%) 2 (1.9%)	(Lore et al., 2005)

Leuconostoc mesenteroides	Suusac (n=15)	3.6 -4.4	MRS	Anaerobically	30°C	72	n(24%)	(Khedid et al., 2009)
Leuconostoc mesenteroides subsp. *mesenteroides*	Raw milk (n=30)	ND	M.S.E.	Aerobically	21°C	72–144	5 (4.2%)	(Khedid et al., 2009)
Leuconostoc mesenteroides subsp. *cremoris*	Raw milk (n=30)	ND	M.S.E.	Aerobically	21°C	72–144	3 (2.5%)	(Khedid et al., 2009)
Leuconostoc mesenteroides subsp. *dextranicum*	Raw milk (n=30)	ND	M.S.E.	Aerobically	21°C	72–144	2 (1.7%)	
Leuconostoc lactis	Raw milk (n=30)	ND	M.S.E.	Aerobically	21°C	72–144	4 (3.3%)	(Khedid et al., 2009)
	Shubat (n=7)	3.7-4.1	MRS	Aerobically	37°C	48	4(10%)	(Rahman et al., 2009)
Streptococcus thermophilus	Pooled milk (n = 5)	6.5 ± 0.1	MRS	Anaerobically	37°C	48	1 (6.3%)	(Jans et al., 2012)
	Suusac (n = 24)	4.9 ± 0.9	MRS M17	Anaerobically Aerobically	37°C 30°C 45°C	48 24 48	27 (19.4%) 14 (13.6%)	
Streptococcus lactis	Raw milk (n=30)	ND	M17	Aerobically			11 (9.2%)	(Khedid et al., 2009)
	Gariss (n=24)	3.41-3.82	M17	n	25°C	48	12(28-80%)	(Hassan et al., 2008)
Streptococcus lactis subsp diactylactis	Gariss (n=24)	3.41-3.82	M17	n	25°C	48	12(20-74%)	
Weissella confusa	Local collection point (n = 5)	6.4 ± 0.2	MRS	Anaerobically	37°C	48	10 (55.4%)	(Jans et al., 2012)
	Final market (n = 4)	6.2 ± 0	MRS	Anaerobically	37°C	48	14 (46.7%)	
	Suusac (n = 24)	4.9 ± 0.9	MRS	Anaerobically	37°C	48	13 (9.4%)	
Weissella helleca	Shubat (n=7)	3.7-4.1	MRS	Aerobically	37°C	48	1(3%)	(Rahman et al., 2009)

Pediococcus acidilactici *Pediococcus damnosus* *Pediococcus pentosaceus*	Raw milk (n=30) Raw milk (n=30) Raw milk (n=30)	ND ND ND	MRS MRS MRS	Aerobically Aerobically Aerobically	30°C 30°C 30°C	48 48 48	3 (2.5%) 2 (1.7%) 1 (0.8%)	(Khedid et al., 2009)
Aerococcus viridans	Raw milk (n=21)	ND	MRS	Anaerobically	37°C	48	1 (9%)	(Hamed and Elattar, 2013)
Vagococcus spp.	Pooled milk (n = 5)	6.5 ± 0.1	MRS M17	Anaerobically Aerobically	37°C 30°C	48 24	3 (18.8%) 2 (11.8%)	(Jans et al., 2012)

* ND= not detected, n= not mention.

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