Improved survival of *Lactobacillus paracasei* NFBC 338 in spray-dried powders containing gum acacia

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Aims: To assess the protective effect of gum acacia (GA) on the performance of *Lactobacillus paracasei* NFBC 338 during spray-drying, subsequent storage and exposure of the culture to porcine gastric juice.

Methods and Results: For these studies, *Lact. paracasei* NFBC 338 was grown in a mixture of reconstituted skim milk (10% w/v) and GA (10% w/v) to mid log phase and spray-dried at outlet temperatures between 95 and 105°C. On spray drying at the higher air outlet temperature of 100–105°C, the GA-treated culture displayed 10-fold greater survival than control cells. Probiotic lactobacilli in GA-containing powders also survived dramatically better than untreated cultures during storage at 4–30°C for 4 weeks. A 20-fold better survival of the probiotic culture in GA-containing powders was obtained during storage at 4°C while, at 15 and 30°C, greater than 1000-fold higher survival was obtained. Furthermore, the viability of probiotic lactobacilli in GA-containing powders was 100-fold higher when exposed to porcine gastric juice over 120 min compared with the control spray-dried culture.

Conclusions: The data indicate that GA has applications in the protection of probiotic cultures during drying, storage and gastric transit.

Significance and Impact of the Study: Gum acacia treatment for the manufacture of probiotic-containing powders should result in more efficient probiotic delivery to the host gastrointestinal tract.

INTRODUCTION

The consumption of probiotics has been shown to confer a number of health benefits on humans, including alleviation of lactose intolerance, prevention and treatment of infectious diarrhoea, modulation of the immune response leading to prevention of the onset of allergic diseases and potential in the management of inflammatory bowel diseases (for reviews see Shanahan 2000; Andersson *et al.* 2001). In order for probiotic cultures in foods to exert beneficial effects, they must fulfil a range of requirements, both functional and technological, for successful delivery in sufficient concentrations in an active form to the host (Shah 2000). Probiotic cultures for human use should be viable at the target site in the host to exert beneficial effects and be non-pathogenic (FAO/WHO 2001). For the development of dairy-based functional foods containing high numbers of viable probiotics, the culture should have the ability to grow in milk-based media, remain viable and retain probiotic properties during production and storage (shelf-life) of the probiotic food product (Knorr 1998; Saxelin *et al.* 1999).

The harsh conditions of the gut, including the acidic nature of the stomach and the presence of bile in the intestine, can adversely affect the viability of probiotic cultures following consumption. Studies *in vitro* and *in vivo* have shown that the nature of the food harbouring the probiotic culture has an effect on subsequent viability following consumption (Gardiner *et al.* 1999). For example, the addition of Cheddar cheese harbouring probiotic cultures to gastric juice led to enhanced probiotic survival in this environment compared with yoghurt (Gardiner *et al.* 1999). In addition to the superior buffering capacity of Cheddar cheese compared with yoghurt, protection was also

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afforded by the dense matrix and high fat content of the cheese. In a study by Rao et al. (1989), *Bifidobacterium pseudolongum*, when protected by microencapsulation, survived a simulated gastric environment in larger numbers than the unprotected culture.

Spray-dried powders harbouring high levels of viable microorganisms provide a convenient form of these cultures for storage purposes and applications in functional food developments (Silva et al. 2002). However, a major limitation of spray-drying of probiotic cultures is the loss of viability which occurs during processing and storage of the powders (Daemen and van der Stege 1982; Gardiner et al. 2000; Desmond et al. 2001). The survival rate of the culture during spray drying and subsequent storage depends upon a number of factors, including the species and strain of culture, the drying conditions, the inoculum and medium used, predadaptation of the culture to acquire resistance to processing conditions and the use of protective agents (Teixeira et al. 1995; Bielecka and Majkowska 2000; Conrad et al. 2000; Gardiner et al. 2000; Desmond et al. 2001). The viability of the probiotic *Lactobacillus paracasei* NFBC 338 following spray-drying was shown to be poor and inversely related to storage temperature (Gardiner et al. 2000). Although the viability of this probiotic strain during spray-drying was enhanced by environmental adaptation of the probiotic culture (in milk) to heat and salt stress prior to drying (Desmond et al. 2001), the stability of the dried culture during storage was not markedly enhanced. The addition of thermoprotectants, such as trehalose (Conrad et al. 2000), non-fat milk solids and/or adonitol (Selmer-Olsen et al. 1999), growth-promoting factors, including prebiotics such as starch, oligosaccharides (Modler et al. 1990; Mituoka 1992) and granular starch (Crittenden et al. 2001) have been employed to improve culture viability during drying, storage and/or gastric transit. Encapsulation, as a means of protecting live cells from extremes of heat or moisture, such as those experienced during drying and storage, is also a technique that is increasingly used in the probiotic food industry (Sheu and Marshall 1993; Millqvist-Fureby et al. 2000; O’Riordan et al. 2001). Various techniques that have been used to form capsules containing cultures include immobilization in calcium alginate beads (Selmer-Olsen et al. 1999; Lee and Heo-Tae 2000) and spray coating with gelatin, xanthan gum or milk fat (Champagne et al. 1995). All of these approaches have had varying degrees of success, depending on the bacterial culture and processing technologies involved. In a recent study by Lian et al. (2002), four strains of bifidobacteria were successfully spray-dried with gum acacia (GA) and other carrier materials such as gelatin and soluble starch. The authors concluded that the survival of these probiotic bacteria varied with strains and is highly dependent on the carriers used.

Gum acacia is an exudate gum from trees of various *Acacia* species, particularly *Acacia* Senegal. It consists mainly of a highly complex polysaccharide of a branched β-(1,3)-linked galactose backbone with branches through the 1,6 positions, with arabinose, rhamnose and uronic acids in ramified side-chains (Menzies et al. 1996). This gum is useful for its functional properties (stabilizing and emulsifying) in several applications in the food and pharmaceutical industries and also in painting (Fauconnier et al. 2000; Bertolini et al. 2001). For use in the probiotic food industry, GA has the added advantages of providing the health benefits associated with dietary fibre (Ferguson et al. 1995; Zimmaro Bliss et al. 2001), showing antibacterial activity against periodontal pathogens (Clark et al. 1993) and causing a rapid change in faecal flora when provided as part of the human diet (Wyatt et al. 1986). In this study, we examined the usefulness of the soluble fibre, GA, for enhancing the stability of dried *Lact. paracasei* NFBC 338 during powder storage and in simulated gastric transit, using *in vitro* studies with gastric juice.

**MATERIALS AND METHODS**

**Bacterial strains and culture conditions**

The probiotic strain *Lact. paracasei* ssp. *paracasei* NFBC 338 (*Lact. paracasei* NFBC 338) was previously isolated from the human gastrointestinal tract (GIT) and obtained from University College, Cork under a restricted materials transfer agreement. Harvested cells of this strain were stored as stock solutions in 50% (v/v) aqueous glycerol at −20°C. *Lactobacillus paracasei* NFBC 338 was subcultured at 1% (v/v) in MRS broth (Oxoid) for ~17 h at 37°C under anaerobic conditions obtained by placing one activated Anaerocult A gas pack (Merck, Darmstadt, Germany) in a jar, which was then sealed.

For the enumeration of viable microorganisms from spray-dried powders, the milk and manufactured powders were pour-plated in duplicate on MRS agar (Oxoid). The powder was resuspended in 10% (w/v) maximum recovery diluent (Oxoid) at 37°C for 1 h and the appropriate serial dilutions prepared before pour-plating on MRS agar.

**Utilization/degradation of gum acacia by *Lactobacillus paracasei* NFBC 338**

Gum acacia was purchased under the brand name Fibregum from Colloides Naturels International (Rouen, France). MRS broths were prepared from first principles (de Man et al. 1960), without a carbohydrate source (minus CHO), and with 1, 5, 10 or 20% (w/v) GA as the sole carbohydrate source. A 1% (v/v) overnight culture of *Lact. paracasei*
NFBC 338 was inoculated into fresh MRS broth and incubated anaerobically at 37°C. The cultures were removed and enumerated on MRS agar throughout 24 h of incubation for growth.

The influence of gum acacia on environmental stress

The usefulness of GA in protecting Lact. paracasei NFBC 338 against stress was examined as follows. A mixture of reconstituted skim milk (RSM; 10% w/v) and GA (10% w/v) was inoculated at 1% (v/v) and grown to early log phase (4–4.5 h). This culture was then subjected to the following environmental stresses with constant agitation: (i) 1·0 mol l\(^{-1}\) H\(_2\)O\(_2\); (ii) 10% (w/v) bovine bile salts (Sigma) for 30 min each at 37°C and (iii) heat stress at 60°C for 30 min. For the control, Lact. paracasei NFBC 338 was grown in 20% (w/v) RSM to early log phase as above and subjected to identical environmental stress conditions. Survival of the culture was monitored by sampling at regular intervals and enumerating on MRS agar.

Fermentation of milk with Lactobacillus paracasei NFBC 338 for spray-drying

Reconstituted skim milk (10% w/v) was heat-treated at 90°C for 30 min, before incorporating an equal quantity of GA at 37°C. Similarly, 20% (w/v) RSM was prepared and heat-treated at 90°C for 30 min. Both milk-based media were inoculated at 1% (v/v) with a fresh overnight culture of Lact. paracasei NFBC 338 and incubated anaerobically at 37°C to exponential phase (4–4.5 h), until a 0·2 drop in pH was obtained. The percent solids of the milks was determined using a percent solids determiner (Labwave 9000; Metrohm, Dublin, Ireland).

Spray-drying of Lactobacillus paracasei NFBC 338

A laboratory scale spray-dryer (B191 mini spray dryer; Buchi, Flawil, Switzerland) was used at a constant air inlet temperature of 170°C. The fermentate was atomised into the drying chamber using a two-fluid nozzle and the product dried almost instantaneously with a very low residence time. The outlet temperature was varied between 95–100°C and 100–105°C. The percent survival of the probiotic culture at each of the outlet temperatures was calculated as described in Desmond et al. (2001) by plating on MRS agar.

The probiotic-containing powders were placed in sealed polythene bags and stored at 4, 15 and 30°C and the viability of Lact. paracasei NFBC 338 determined on the day of powder manufacture and during powder storage for up to 8 weeks.

Scanning electron microscopy of spray-dried powders

The powders were spread thinly onto a double-sided carbon adhesive disc and then anchored to the electron microscope (EM) stub. The samples were then gold coated (K550; Emitech Ltd., Kent, UK) and examined in an electron microscope (S-4700 Field Emission Scanning; Hitachi High-Technologies, Tokyo, Japan) at an accelerating voltage of 15·0 kV.

Moisture content and water activity measurements in spray-dried powders

The moisture content of spray-dried powders was determined by oven-drying at 102°C, according to the International Dairy Federation Bulletin (IDF 1993). The water activity (a\(_w\)) was determined using a percent solids determiner (Labwave 9000; Metrohm, Dublin, Ireland) and Aqualab CX-2 (Decagon Devices, Pullman, WA, USA) according to the manufacturer’s instructions.

Sodium chloride content of spray-dried powders

The salt content of the spray-dried powders was determined according to IDF (1979). The powders were rehydrated in sterile deionized water at 10% (w/v) and acidified with nitric acid before titration of the chloride ion with a standard volumetric silver nitrate solution using a measuring electrode, according to the procedure described in IDF (1979). The salt content was expressed as % NaCl g\(^{-1}\) and the determination was performed in duplicate for each powder sample.

Survival of dried Lactobacillus paracasei NFBC 338 in porcine gastric juice

Gastric contents, collected from 16 porcine stomachs immediately after slaughter (obtained from a local abattoir), pH range 2·1–4·0, were pooled and filtered twice through glass wool. Porcine gastric juice was obtained by centrifugation twice at 13 000 g for 30 min (Gardiner et al. 1999). The pH of the gastric juice was adjusted (at room temperature) to 3·0 using 1 mol l\(^{-1}\) HCl. The gastric juice was checked for sterility by plating on GM17 and MRS agar and incubating both aerobically and anaerobically at 37°C for 3 d. There was no growth on any of the media tested and the sterile gastric juice, pH 3·0, was stored at –20°C until use.

Spray-dried powders were added to sterile gastric juice (1% w/v) at 37°C and vortex mixed for 1 min. The pH was immediately adjusted to 3·0 using 1 mol l\(^{-1}\) HCl and the survival of Lact. paracasei NFBC 338 monitored throughout incubation for 120 min (with constant agitation). Samples were taken in duplicate at regular intervals for enumeration.
of the probiotic lactobacilli. The pH was monitored throughout incubation using a pH meter (Mettler Toledo; Alpha Technologies, Dublin, Ireland). The experiment was performed in triplicate.

RESULTS

Metabolism of gum acacia by *Lactobacillus paracasei* NFBC 338

Gum acacia did not have a growth-stimulating effect on *Lact. paracasei* NFBC 338 over 24 h of growth in MRS broth, when provided at levels of between 1 and 20% (w/v) as the sole carbohydrate source (data not shown). The mean generation time (g) was calculated following growth in the different media and for each of the media tested, was found to be in the range 1.05 ≤ g ≤ 1.5 h.

The influence of gum acacia on environmental stress

Initially, it was determined whether GA could offer cells protection against lethal doses of H2O2, temperature and bile in vitro. On examining the effect of H2O2 stress on the probiotic strain, it was found that 15 min exposure to 1 mol l\(^{-1}\) H2O2 was bactericidal for *Lact. paracasei* NFBC 338 grown in 20%(w/v) RSM (the control) with viable cell numbers reduced by 6 log from 6.03 × 10\(^6\) cfu ml\(^{-1}\) (Fig. 1a). In contrast to this, the addition of GA to the culture medium afforded an efficient level of protection (100-fold) during 15 min H2O2 exposure, with *Lact. paracasei* NFBC 338 cell numbers decreasing from 1.37 × 10\(^7\) to 2.9 × 10\(^3\) cfu ml\(^{-1}\) (Fig. 1a). Following a further 15 min stress in 1 mol l\(^{-1}\) H2O2, the viability of the GA-treated culture decreased a further 10-fold to 1.57 × 10\(^2\) cfu ml\(^{-1}\).

Heat stress at 60°C for 30 min resulted in ≥3 log reduction in viable numbers of both the control and GA-treated *Lact. paracasei* NFBC 338, with greater than 99% of the culture killed after just 20 min heat shock in each case (Fig. 1b). Likewise, during exposure to bile stress (10% w/v) for 30 min, the viability of control and GA-treated *Lact. paracasei* NFBC 338 declined at similar rates, with ≤ 20 log cfu ml\(^{-1}\) reduction in cell numbers in each case (Fig. 1c). Thus, although GA gave significant protection against H2O2-induced oxidative killing, the protective effect against heat and bile was less dramatic.

Effect of gum acacia on the survival of *Lactobacillus paracasei* NFBC 338 during spray drying

The percent survival of *Lact. paracasei* NFBC 338, spray-dried in 10% (w/v) RSM and 10% (w/v) GA, was significantly different from the survival of control cultures (dried in 20% w/v RSM) at higher temperatures. At an outlet temperature of 100–105°C, less than 0.01% of control *Lact. paracasei* NFBC 338 survived spray-drying, while the viability of the GA-treated culture was 10-fold higher (0.9 ± 1.3%) following drying under these conditions. However, no differences were obtained in cell viability following spray-drying at the lower outlet temperature of 95–100°C, where 1.7 ± 2.4% of *Lact. paracasei* NFBC 338 prepared in 20% (w/v) RSM survived, compared with 1.4 ± 0.8% survival of the GA-treated culture.

Scanning electron microscopy of spray-dried powders

Figure 2 shows the scanning electron micrographs of control and GA-treated powders. Both milk and GA microparticles were spherical in shape and varied in size from 5 to 15 μm on average. In addition, the surface of GA microparticles also showed what has previously been described by Lian.
et al. (2002) as ‘a flat ball effect’, which was not evident for the skim milk microparticles.

Effect of gum acacia on the survival of *Lactobacillus paracasei* NFBC 338 during powder storage

The viability of spray-dried *Lact. paracasei* NFBC 338 in GA-containing powders was superior to the control powders during storage at 4, 15 and 30°C for up to 4 weeks (Table 1). The stability of spray-dried *Lact. paracasei* NFBC 338 was highest during storage at 4°C, with the viability of probiotic cultures decreasing as the storage temperature increased. The rate of decline of viable probiotic lactobacilli during 8 weeks increased when powders were stored at 15 and 30°C. The protective effect of GA remained evident up to 4 weeks storage at both 15 and 30°C, with GA-treated *Lact. paracasei* NFBC 338 in spray-dried powders manufactured at outlet temperatures between 95 and 105°C surviving up to 3 log better than control cells that had been dried and stored under the same conditions. Beyond 4 weeks of storage at both 15 and 30°C, the decline in viability of both control and GA-containing powders continued at the same rate, such that the viability of the probiotic powders was reduced by more than 99.9% following 8 weeks of storage.

Characterization of spray-dried probiotic powders

The moisture content of GA-containing probiotic powders manufactured at 95–105°C ranged from 2.76 to 2.53% H₂O g⁻¹, while the moisture content of control powders manufactured under the same conditions was slightly higher, from 3.24 to 2.67% H₂O g⁻¹ (Table 2). The salt contents of the control (containing 20% w/v RSM) powders were two-fold greater than those of GA-containing powders due to the high salt content of RSM (Table 2).

The *a*<sub>w</sub> values of GA-containing and control powders did not differ dramatically (Table 3). For example, GA-containing powders produced at 95–100°C and stored at 15°C had an *a*<sub>w</sub> of approx. 0.30, while control powders produced and stored under the same conditions had an *a*<sub>w</sub> of approx. 0.29.
Results are the mean of triplicate trials.

RSM, Reconstituted skim milk.

Survival of gum acacia-treated and control Lactobacillus paracasei NFBC 338 in porcine gastric juice

As a model for the performance of the dried probiotic preparations during gastric transit, the survival of the strain in each powder was investigated when exposed to porcine gastric juice for up to 120 min. Lactobacillus paracasei NFBC 338 in GA-containing powders was more resistant to acid stress than control cells when exposed to gastric juice (pH 3.0) for up to 120 min (Fig. 3). Following addition of the powders, there was a greater than 6 log reduction in the viability of the spray-dried probiotic (with counts decreasing from 7.3 x 10^7 to 2.71 x 10^1 cfu ml^-1), while the viability of GA-treated Lact. paracasei NFBC 338 was reduced by only 4 log cfu ml^-1 following 120 min exposure at 37°C.

DISCUSSION

The success of probiotic-containing foods depends not only on their health-promoting properties but also on the viability of probiotic bacteria in the product during its shelf-life, as well as resistance of the bacteria to the harsh conditions existing in the GIT. This study investigated the potential for enhancing probiotic viability during powder storage and gastric transit by incorporation of the soluble fibre GA.

To determine whether GA could be used to protect live cells during unfavourable environmental conditions, a GA-treated Lact. paracasei NFBC 338 culture was exposed to stressful levels of heat, H_2O_2 and bile salts and survival compared with that of a control untreated culture. This initial study could then be used to predict the survival of the GA-treated probiotic during spray-drying, the rate of inactivation during storage and gastric transit tolerance. Gum acacia treatment protected the probiotic culture during bile salt and heat stress to a minor extent, with less than 10-fold better survival of GA-treated cells compared with the control in each case. During H_2O_2 stress, however, it was found that GA treatment afforded protection to Lact. paracasei NFBC 338 such that 100-fold more GA-treated cells survived the 15-min challenge period when compared with control cells. The mechanism by which GA protects against the damaging effects of oxidative stress in this study is not known, especially since previous studies revealed that GA is porous to oxygen (Bertolini et al. 2001). The use of GA to protect against oxidation has, however, previously been reported; Minemoto et al. (2002) demonstrated that linoleic acid encapsulated in GA was more resistant to oxidation than that in a maltodextrin-based microcapsule.

On examining the potential of GA as a protectant of Lact. paracasei NFBC 338 during spray drying at different outlet temperatures, it was found that the addition of GA to the liquid feed prior to drying enhanced survival at the higher outlet temperatures tested. Significant protection of GA-treated Lact. paracasei NFBC 338 during the heat stress associated with spray-drying was not expected, however, given that the previous heat stress study showed that GA did not afford thermoprotection to the culture in RSM. Using GA as a thermoprotectant for live bacteria during spray-drying has previously been reported by Lian et al. (2002) and for aromatic monoterpenes by Bertolini et al. (2001). In the latter study, it was reported that the

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recovery of GA-encapsulated monoterpenes following spray drying was similar to previously published values using other encapsulating materials such as maltodextrin (Risch and Reineccius 1995).

Cell injury and inactivation occur not only during processing, but also during storage of dried cultures. This decrease in viability is markedly influenced by the water properties of the suspending medium in which the live bacteria are dried and also on the temperature and relative humidity conditions of the powder storage environment (Abd El Gawad et al. 1989; Selmer-Olsen et al. 1999; Gardiner et al. 2000). Spray-dried cultures retain viability for longer at low temperatures; however, refrigeration (4–7°C) is expensive to both suppliers and retailers of probiotic products and thus there is a need to produce probiotic cultures that are stable at ambient temperatures. In this study, the aims were to achieve higher survival of the probiotic culture immediately after drying and to slow down the rate of inactivation during storage. The results showed that viable lactobacilli in powders manufactured at each outlet temperature decreased gradually during storage. However, this decrease in viability differed depending on pretreatment of the culture and the storage temperature. During storage at each of the temperatures tested, the stability of dried Lact. paracasei NFBC 338 was significantly greater in the presence of GA. When spray-dried, GA forms a semipermeable wall around the other components that make up the liquid feed going into the drier (Bertolini et al. 2001). The higher survival rate of GA-treated Lact. paracasei NFBC 338 at elevated storage temperatures observed in this study suggests that GA may offer protection against oxidative stress as observed earlier and/or the rate of water removal from the immediate environment of live cells is reduced by the presence of a semipermeable GA wall. Gum acacia has been extensively used as an encapsulating agent for the retention and protection of chemically reactive and volatile oils and flavour compounds in commercial food flavourants (McNamee et al. 2001). Following 8 weeks of storage, the protective effect of GA on the stability of dried Lact. paracasei NFBC 338 declined considerably. This was not unexpected, considering the dramatic decrease in viability of unprotected control cells in the same time period. In a similar study, it was reported that the use of a carrier material composed of poly vinyl pyrrolidone and dextran to encapsulate Enterococcus faecium during spray-drying resulted in an increase in viability of up to 15% following 4 months of storage at room temperature when compared with a non-encapsulated control (Millqvist-Fureby et al. 2000). However microencapsulation with starch proved to be unsuitable for use as an encapsulating material for a probiotic Bifidobacterium strain during spray-drying, storage and acid-stress conditions (O’Riordan et al. 2001).

Analysis of the probiotic powders showed that, as the outlet temperature of spray drying increased, the moisture content of spray-dried powders decreased, for both GA-containing and control powders. The values obtained are in agreement with previous reports (Desmond et al. 2001) and did not exceed the level required for prolonged powder storage life and stability (4%) (Masters 1985). Not surprisingly, the $a_w$ of the probiotic powders decreased with increasing storage temperature, an observation previously reported for probiotic powders (Teixeira et al. 1995); however, there was no dramatic difference in $a_w$ between treatments. Typical $a_w$ values that are desirable for the survival of bacterial populations dried in milk-based media are within the range 0.28–0.65 (Kosanke et al. 1992), a range that encompasses the $a_w$ of all powders manufactured in this study. The salt content of GA-treated and control powders differed greatly. The lower salt content of GA compared with RSM could contribute to its appeal for use as an ingredient in health-promoting foods.

For probiotic bacteria in foods to be beneficial in the host, they should be able to survive gastric transit and reach the small intestine in sufficient numbers to be effective. The harsh environment of the GIT is mainly attributed to the low pH conditions of the stomach, in addition to the presence of bile in the small intestine. In this study, the viability of GA-treated and control spray-dried probiotic bacteria was assessed following exposure to porcine gastric juice in vitro at 37°C. As testimony to the bactericidal environment of the GIT, there was a 3 log reduction in cell numbers following just 1 min exposure of both control and GA-treated probiotic cultures to porcine gastric juice at pH 3.0. However, results show that, for up to 120 min, the GA-treated culture survived 2 log better than unprotected control cells. It has been proposed that milk proteins function as buffering agents in vivo, thereby protecting ingested bacterial strains during upper gastrointestinal transit (Charteris et al. 1998). Given that GA is not digested by human intestinal enzymes (Phillips 1998), it should reach the colon unaltered, where it may exert a prebiotic effect. Moreover, it is likely that the GA-treated culture in this study has the added advantage of providing a physical barrier for protection during gastric transit. Recent studies (Lee and Heo-Tae 2000; Sultana et al. 2000; O’Riordan et al. 2001), using calcium alginate-encapsulated probiotic bacteria, did not demonstrate a significant improvement in cell survival when they were subjected in vitro to high acid and bile salt conditions, whereas immobilization of a Bifidobacterium strain in gellan–xanthan beads did enhance survival of the culture by greater than 8 logs in simulated gastric juice at pH 2.5 (Sun and Griffiths 2000).

The data indicate that there is a technological benefit achieved by the addition of GA to the suspending medium.
prior to spray-drying, in order to preserve the viability of dried Lact. paracasei NFB C 338 during storage at elevated temperatures and potentially during gastric transit. This beneficial effect on probiotic viability and stability may be due to encapsulation, thereby protecting the live cells from surrounding adverse environmental conditions. Gum acacia treatment for the manufacture of probiotic-containing powders should result in more efficient probiotic delivery to the host GIT.

ACKNOWLEDGEMENTS

C.D. is in receipt of a Teagasc Walsh Fellowship. The authors thank Dr William Carroll (NUI, Galway, Ireland) for SEM work. This work was funded by the Irish Government under the National Development Plan 2000–2006, the European Research and Development Fund and by EU Project QLKI-C T- 2000-30042.

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