Effect of nucleation on the likeability and drinking rate of lager in social alcohol drinkers

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Abstract

Background. The aim of these studies was to investigate the effect of nucleated glasses on the likeability and drinking rate of lager in social alcohol drinkers.

Methods. In Study 1, participants (*n* = 116) were asked to taste two glasses of lager (280 ml each) in separate 5-minute taste tests and fill out a likeability questionnaire (items on a 100 mm visual analogue scale (VAS)) after each glass in a within-subjects design with one factor of glass (nucleated, non-nucleated). In Study 2, participants (*n* = 160) were asked to consume a pint of lager (568 ml) and fill out a likeability questionnaire in a between-subjects design with one factor of glass (nucleated, non-nucleated).

Results. There was no clear evidence that likeability of lager differed between nucleated and non-nucleated glasses in either study. In Study 1, there was strong evidence (nucleated: 74.2, non-nucleated: 64.0, MD = 10.2, 95% CI: 6.1, 14.2, $p < 0.001$) that lager in nucleated glasses was more visually appealing (single item from likeability measure) than lager in non-nucleated glasses. In Study 2, there was no clear evidence (nucleated: 16.9 mins, non-nucleated: 16.3 mins, MD: 0.6 mins, $p = 0.57$) that lager was consumed at different rates from nucleated and non-nucleated glasses.

Conclusions. Nucleated lager glasses do not appear to alter the likeability or consumption (volume consumed or drinking rate) of lager, although they do seem to increase the visual appeal of lager.

Short Summary

The nucleation of lager glasses appears to increase the visual appeal of lager but does not alter overall likeability (calculated by averaging ratings of visual appeal, enjoyment, refreshment, tastiness and likelihood to buy). Nucleation does not appear to alter consumption of lager either in terms of volume consumed or drinking rate.

Introduction

The alcohol industry utilises glassware as an effective vehicle to recruit customers, revive brands, build profits and increase consumption by capitalising on the immediacy of glassware to the point of consumption (Stead et al., 2014). A recent development is the addition of nucleated bases in lager glasses. Research is needed to establish what effect this design feature has on the likeability and drinking rate of lager, as this could have implications for population level alcohol consumption.

Nucleation is a process in supersaturated solutions whereby gases such as carbon dioxide (CO_2) are released. Bubbles of CO_2 molecules grow on nucleation sites which usually come in the form of hollow, cylindrical cellulose fibres (Liger-Belair, 2005; Prins, 1998) and are released from these sites when they reach a critical size and ascend through the solution. Bubbles rapidly grow in size as they ascend as well increasing in speed as they travel upward (Shafer & Zare, 1991). Modern lager glasses concentrate the nucleation process by having either a laser-etched or printed nucleated stamp on the inner base, which allows CO_2 to be more rapidly released.

A paucity of studies have examined correlates of nucleation such as the head of a beer (which can be maintained for longer by nucleation) and CO_2 content (which can be increased by nucleation). Beer with a sizable head has been judged to taste better than a beer with less head (Bamforth, 2000). Italian consumers concluded that beer with a medium (compared to larger or smaller) level of foam was the best dispensed, most visually appealing, most attractive to consume and most likely to be purchased (Donadini et al., 2011). Beers of higher CO_2 content have been perceived as more bitter (Kosin et al., 2012; Ono et al., 1983) and CO_2 has been deemed to have an important role in conveying beer flavour, aroma delivery and mouth feel (Carroll, 1979; Clark et al., 2011; Meilgaard, 1982).

The effect of nucleation on the drinking experience of champagne and other sparkling wines has been studied more extensively and can inform our understanding of the experience of consuming a nucleated lager. Nucleation in sparkling wines produce rising

bubbles that impact the visual perception of wine before the act of tasting and inhaling has begun (Liger-Belair, 2005). The aromatic perception of sparkling wine is due to bursting bubbles releasing gaseous CO_2 and volatile organic compounds above the wine surface (Liger-Belair et al., 2013; Priser et al., 1997; Tominaga et al., 2003). Dissolved CO_2 and collapsing bubbles in the oral cavity interact with trigeminal receptors which are responsible for face sensations (Dessirier et al., 2000; Kleemann et al., 2009; Meusel et al., 2010) and gustatory receptors which are responsible for taste sensations (Chandrashekar et al., 2009; Dunkel & Hofmann, 2010). These reactions may influence a lager drinker in similar ways.

In summary, 'head' and CO_2 content, which are altered by nucleation, appear to affect the sensory experience of consuming lager. In Study 1, we investigated the effect of nucleated glasses on self-report likeability of lager and amount consumed in a 5 minute period. We hypothesised that lager in nucleated glasses would be rated as more likeable than lager in non-nucleated glasses. In Study 2, we investigated the effect of nucleated glasses on the likeability and drinking rate of lager. We hypothesised that there would be a difference in drinking rate between the glasses, but this was a non-directional hypothesis. If the likeability of lager in nucleated glasses is greater than in non-nucleated glasses, this may speed up consumption due to a more pleasant and rewarding drinking experience. In contrast the increased effervescence may lead consumers to savour the more likeable drinking experience and be less concerned with finishing the drink before it goes "flat".

Study 1

Methods

Design and overview. This was a laboratory experimental study. We used a within-subjects, double-blind design with one factor of glass type (nucleated, non-nucleated). The presentation order of the glasses was counterbalanced, and each condition was populated with an equal number of participants stratified by sex. Ethics approval was granted by the Faculty of Science Research Ethics Committee at the University of Bristol (reference: 29011512321) and the study was conducted in accordance with the principles of the

Declaration of Helsinki (2013) and Good Clinical Practice guidelines (6th revision). Written informed consent was obtained from all participants. The study protocol was registered at http://osf.io/yzvk5 prior to data collection.

Participants. Social alcohol drinkers who reported consuming between 10 and 50 units/week if male or between 5 and 35 units/week if female, were recruited from the staff and students of the University of Bristol, and from the general population by means of poster and flyer advertisements, existing database of participants and word-of-mouth. Participants were required to be in good psychological and physical health, aged between 18 and 40 years, and not currently taking any psychiatric medication. Exclusion criteria included current use of illicit substances (excluding cannabis), a strong family history of alcoholism (defined as at least one first-degree relative or two or more second degree relatives), weighing less than 50 kg if female or 60 kg if male and not drinking/liking lager. Participants were asked to abstain from alcohol consumption for 24 hours prior to the test session and were only enrolled onto the study if they provided a zero breath alcohol concentration reading at the start of the session. Participants were reimbursed £5 or awarded course credit at the end of the study.

Materials. The alcoholic beverage used was standard strength lager (Budweiser™ 4.8% alcohol by volume [ABV]). Glassware used were Senator beer glasses (volume: 280 ml; Figure 1) designed by Paşabahçe. One was a 'Super Activator Max' nucleated glass, and the other was non-nucleated. The glasses were identical in all other respects.

Figure 1. Senator beer glass (left) with its nucleated base (right).

Questionnaire measures comprised the Alcohol Use Disorder Identification Test (AUDIT) (Saunders, Aasland, Babor, de la Fuente, & Grant, 1993) and a Lager Drinking Experience Questionnaire (LDEQ) amended from a taste test questionnaire used with permission from colleagues at the University of Liverpool (Field et al., 2007; Field & Eastwood, 2005; Jones et al., 2011). The LDEQ contains ten questions ("How smooth is this drink?", "How light is this drink?", "How sweet is this drink?", "How intoxicating is this drink?", "How bubbly / gassy is this drink?", "How visually appealing is this drink?", "How enjoyable is his drink?", "How refreshing is this drink?", "How tasty is this drink?", "How likely would you be to buy this drink?") which were rated on a 100 mm VAS from "Not at All" to "Extremely".

Procedure. Participants attended one study session lasting approximately 30 minutes. Participants were sent the information sheet in advance of the study session and were given the opportunity to read it again upon arrival and ask questions. After informed consent had been obtained, a screening procedure was conducted to assess eligibility for the study, based on inclusion/exclusion criteria. Recent alcohol consumption was assessed by breath test (AlcoDigital 3000, UK Breathalysers) and weight was recorded.

For the main session, participants were asked to turn their phone off and place it out of reach. They were presented with 100 ml of water as a thirst quencher and told to consume as much as they liked. Baseline testing begun with participants completing the AUDIT. While the AUDIT was being completed, 280 ml of lager was poured into a glass (either nucleated or non-nucleated glass as per randomisation) by a second experimenter (to maintain double-blinding) in a nearby kitchen and delivered to the test room. Drinks were chilled prior to serving and were poured immediately prior to consumption to ensure that carbonation was consistent across participants. The second experimenter presented the drink to the participant and the primary experimenter instructed the participant to consume as much of the drink as they wanted over a duration of 5 minutes, complete the LDEQ whilst doing so and place the glass in an adjacent box (to maintain double-blinding) when finished. The drinking phase started after the primary experimenter said “You may begin” and was recorded by stop-watch. The primary experimenter left the room for 5 minutes and then returned with another 100 ml of water for the participant to cleanse their palette. Participants were then given a magazine, and a 5-minute break commenced. The primary experimenter returned to the room after the 5-minute break was over. The second experimenter prepared another 280 ml of lager (either nucleated or non-nucleated glass as per randomisation) and delivered it to the test room. The procedure followed for the first drink was repeated and the same instructions were given. After the drink was consumed, participants were asked did they prefer Drink 1 or Drink 2.

Before leaving the testing room, participants were asked to read and sign a safety form that advised them that they had received alcohol and that they should not drive, cycle, operate machinery or engage in any other task or behaviour considered potentially hazardous after alcohol consumption. Participants were debriefed and reimbursed. Participants were offered the opportunity to stay behind to allow any effects of alcohol to wear off and a taxi home. When the participant left, the primary experimenter measured the remaining volume from the first and second drink (the participant was naïve to this).

Statistical analysis. A previous study investigating the effect of beverage packaging on the palatability of alcoholic beverages indicated an effect size from standardised difference scores (*dz*) of 0.27 (given a correlation of $r = 0.74$ between responses in the two conditions) for the difference in the palatability ratings of beer between a blind and non-blind condition (Gates et al., 2007). To detect the same effect size, we required a sample size of 110 in order to achieve 80% power at an alpha level of 5%. This was increased to 112 participants to allow for equal numbers of males and females in each glass condition.

Questionnaire responses were captured via online survey platforms (Bristol Online Survey & Qualtrics) and imported into SPSS. Volume consumption data was extracted from case report forms. Data from five questionnaire items in the LDEQ ("How visually appealing was the drink?"; "How enjoyable was the drink?"; "How refreshing was the drink?"; "How tasty was the drink?"; "How likely would you be to buy the drink?") were averaged to calculate a likeability score. Other questions ("How smooth was the drink?", "How light was the drink?", "How sweet was the drink?", "How intoxicating was the drink?") acted as filler questions and were not analysed.

The primary outcome was the likeability of lager in nucleated and non-nucleated glasses analysed using a paired-samples *t*-test. Secondary outcomes were the volume consumed from each glass condition, and the responses to the individual questionnaire items that constituted the likeability factor for each glass condition. These were analysed individually using paired-samples *t*-tests. Responses to "How bubbly / gassy is this drink?" for each glass condition were used as a manipulation check. Outliers were detected based on likeability scores via boxplots and defined as 1.5 times the IQR above quartile 3 or below quartile 1. All analyses were conducted using SPSS Statistics Software (IBM SPSS Statistics for Windows, Version 23.0, IBM Corporation).

The data that form the basis of the results presented here and the analysis scripts used to generate them are available from the University of Bristol Research Data Repository (http://data.bris.ac.uk/data/), doi: (to be generated post peer review).

Results

Participants (*n* = 116) were on average 21 years old (*SD* = 4, range 18 to 37) with an AUDIT score of 10 (*SD* = 4, range 4 to 26). 26.7% of participants were low-risk drinkers (AUDIT score: 0-7), 63.8% were hazardous drinkers (AUDIT score: 8-15) and 10.3% were harmful drinkers (AUDIT score: 16+). When asked what drink they preferred, 54% of participants chose the nucleated lager. Four extra participants were tested than planned to balance the number of participants in each condition after a randomisation error occurred during testing.

Manipulation check. A paired-samples *t*-test found strong evidence for a difference in the nucleated compared to the non-nucleated condition suggesting that lager in nucleated glasses was more bubbly / gassy compared to lager in non-nucleated glasses. Removing outliers (*n* = 2) did not meaningfully change the results. These results suggest the experimental manipulation worked as intended (Table 1).

Likeability factor. We found no clear evidence for a difference in overall likeability of lager from a nucleated glass and a non-nucleated glass; but we found strong evidence for a difference in visual appeal of lager consumed from a nucleated glass compared to a non-nucleated glass. There was no clear evidence to suggest meaningful differences in responses to the other three questions constituting the likeability factor. Removing outliers (*n* = 2) did not change any of these effects meaningfully (Table 1)..

Volume consumption. We found no clear evidence for a difference in the volume of lager consumed from a nucleated glass and a non-nucleated glass. Removing outliers (*n* = 2) did not alter these results meaningfully (Table 1).

Table 1. Differences in likeability of lager, aspects of the lager drinking experience and volume of lager consumed between nucleated and non-nucleated conditions.

	Full sample (n = 116)			Outliers excluded (n = 114)		
	MD	95% CI	*p*-value	MD	95% CI	*p*-value
Total (Likeability) Score	0.7	-2.4, 3.9	0.64	0.7	-2.4, 3.8	0.66
Likeability sub-scales:						
Visual Appeal	9.3	5.0, 13.6	<0.001	10.2	6.1, 14.2	<0.001
Enjoyment	2.1	-2.0, 6.2	0.31	2.2	-2.0, 6.4	0.29
Refreshment	3.3	-0.6, 7.2	0.10	3.4	-0.6, 7.4	0.09
Tastiness	0.3	-4.1, 4.7	0.88	0.4	-4.1, 4.9	0.87
Likelihood to Buy	-0.1	-4.9, 4.7	0.96	-0.1	-4.9, 4.8	0.98
Other items:						
Bubbly / gassy	13.9	8.9, 18.9	<0.001	14.1	9.0, 19.1	<0.001
Volume Consumed (ml)	0.4	-9.5, 10.4	0.93	0.7	-9.4, 10.7	0.90

CI = Confidence Interval, MD = Mean Difference.

Study 2

Methods

Design and overview. This was a laboratory experimental study. We used a between-subjects, double-blind design with glass (nucleated, non-nucleated) as the between-subjects factor. Ethics approval was granted by the Faculty of Science Research Ethics Committee at the University of Bristol (reference: 31031633763) and the study was conducted in accordance with the Declaration of Helsinki (2013) and Good Clinical Practice guidelines (6th revision). Written informed consent was obtained from all participants. The protocol was registered at http://osf.io/rcmuj prior to data collection.

Participants. Identical criteria were used to select participants as in Study 1, with an additional exclusion criterion of not having taken part in Study 1 or a previous experiment investigating the effect of glass markings on drinking rate. Participants were reimbursed £7 or awarded course credit at the end of the study.

Materials. The same alcoholic beverage was used as in Study 1. Glassware used were tulip shaped beer glasses (volume: 568 ml; Figure 2) supplied by Paşabahçe. One was a 'Head Keeper' nucleated glass, and the other was non-nucleated. Glasses were otherwise identical.

Figure 2. Tulip beer glass (left) and its nucleated base (right).

Questionnaire measures were identical to Study 1 with the addition of the Alcohol Urges Questionnaire (AUQ) (Bohn et al., 1995) to assess craving for alcohol and the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988) to assess mood. The National Adult Reading Test (NART) (Nelson & Willison, 1991) and an online word search task were also included as dummy tasks.

Procedure. Participants attended one study session lasting approximately 45 minutes. Participants underwent the same pre-experiment procedure and screening as Study 1.

In the main session, participants were asked to turn their phone off and place it out of reach. They were presented with 100 ml of water as a thirst quencher and consumed as much as they liked. Self-report measures of alcohol use (AUDIT), alcohol craving (AUQ) and mood (PANAS) were administered. Participants completed the NART and then received 568 ml of lager (5% ABV Budweiser in a nucleated or non-nucleated glass as per randomisation). Drinks were prepared as per Study 1. Participants were told that they should consume all of the drink at their own pace whilst watching a nature documentary (Earth: The

Journey of a Lifetime, BBC Worldwide 2008). The experimenter started the film (at the same point in the film and in the session for all participants) and left the room. The drinking session was recorded using a video camera (Hitachi Hybrid Camcorder DZHS500E) to allow extraction of drinking times. Participants opened the door when they had finished their beverage, the experimenter returned and presented participants with the LDEQ and an online word-search task in which they were instructed to find as many words as possible in four minutes. This was intended to disguise the nature of the study, and these data were not analysed. Then, measures of alcohol craving (AUQ) and mood (PANAS) were administered again. Finally, participants were debriefed and reimbursed. Before leaving the testing room, the participant underwent the same debriefing and safety protocol as Study 1

Statistical analysis. A previous study indicated a longer drinking time from straight glasses (M = 11.5, SD = 5.6) compared to curved glasses (M = 7.2, SD = 3.3), representing an effect size of d = 0.91 for the difference in drinking rate between the two glass shapes (Attwood et al., 2012). However, in order to be conservative, we recruited a sample size of 160 participants, which provided 80% power at an alpha level of 5% to detect an effect size of d = 0.45, which is equivalent to a difference in drinking rate of 2 minutes (SD = 4.5) between conditions.

Questionnaire responses were captured via online survey platforms (Bristol Online Survey & Qualtrics) and imported into SPSS. Drinking time data was extracted from videos. The primary outcome measure was total drink time (from initiation of first sip to termination of last sip) and we analysed these data in a linear regression, with glass type (nucleated, non-nucleated) as a between-subjects factor. Linear regressions with glass type as predictor adjusting for baseline mood/craving were used to analyse mood (PANAS) and craving (AUQ) data respectively. Responses to the question “How bubbly / gassy was the drink?” served as a manipulation check and was analysed using an independent samples t-test, with glass type as a between-subjects factor. Likeability scores were calculated as in Study 1 and individual questionnaire items that constituted it were analysed using independent samples t-

tests, with glass type as a between-subjects factor. Outliers were detected based on total drinking times via boxplots and defined the same as in Study 1. All analyses were conducted using SPSS Statistics Software (IBM SPSS Statistics for Windows, Version 23.0, IBM Corporation).

The data that form the basis of the results presented here and the analysis scripts used to generate them are available from the University of Bristol Research Data Repository (http://data.bris.ac.uk/data/), doi: (to be generated post peer review).

Results

Participants (*n* = 160; 50% female) were on average 21 years (*SD* = 4, range 18 to 40) and had an average AUDIT score of 9 (*SD* = 4, range = 2 to 22). 45% of participants were low-risk drinkers (AUDIT score: 0-7), 48.8% were hazardous drinkers (AUDIT score: 8-15) and 6.3% were harmful drinkers (AUDIT score: 16+). Two extra participants were tested to replace two participants excluded from analysis due to video malfunctions making their data unusable. Missing questionnaire responses were imputed based on the median of the sample for that specific question. Five outliers were removed based on their drinking time using the same exclusion criterion as Study 1.

Total drinking time. There was no clear evidence that nucleated glasses were associated with total drinking time in the full sample or when outliers (*n* = 5) were removed (Table 2).

Table 2. Effect of nucleation on total drinking time (min:sec/0.6).

	MD	**95% CI**	***p*-value**
Full sample (n = 160)	1.5	-1.0, 4.0	0.25
Outliers excluded (n = 155)	0.6	-1.5, 2.7	0.57

CI = Confidence Interval. MD = Mean difference.

Manipulation check. There was no clear evidence in the full sample or when outliers (*n* = 5) were removed (Table 3) for a difference in responding to the question 'How bubbly / gassy was the drink'?.

Likeability factor. An independent samples *t*-test found no clear evidence for a difference between the likeability of lager from a nucleated glass and a non-nucleated glass (Table 3). Removing five outliers did not meaningfully change the results. There was no clear evidence to suggest differences in responses to the five questions constituting the likeability factor.

Table 3. Differences in likeability of lager and aspects of the lager drinking experience between nucleated and non-nucleated conditions.

	Full sample (*n* = 160)			**Outliers excluded (*n* = 155)**		
	MD	95% CI	*p*-value	MD	95% CI	*p*-value
Total (Likeability) Score	-0.7	-6.6, 5.2	0.82	-0.2	-6.1, 5.8	0.96
Likeability sub-scales:						
Visual Appeal	-1.6	-8.5, 5.3	0.64	-0.3	-7.3, 6.6	0.93
Enjoyment	-2.3	-9.1, 4.6	0.52	-1.5	-8.3, 5.3	0.67
Refreshment	-3.2	-9.2, 2.9	0.30	-3.5	-9.6, 2.7	0.27
Tastiness	1.2	-5.4, 7.9	0.71	1.4	-5.3, 8.1	0.69
Likelihood to Buy	2.3	-5.2, 9.8	0.54	3.1	-4.3, 10.5	0.41
Other items:						
Bubbly / gassy	-0.8	-6.6, 5.0	0.78	-0.3	-6.3, 5.6	0.91

MD = Mean Difference. CI = Confidence Interval.

Reliability analysis. Ratings of total drinking time carried out by two raters were strongly and positively correlated, single measures intraclass correlation (*rs* > 0.96, *ps* < 0.001), indicating a high level of inter-rater reliability.

Discussion

Contrary to our hypotheses, nucleated glassware did not alter the likeability of lager in either study. In Study 1, there was strong evidence that the visual appeal of lager was greater and weak evidence that refreshment was greater when consuming from nucleated compared to non-nucleated glasses. Nucleated glasses did not appear to affect lager consumption in terms of volume consumed in a set time period (Study 1) or drinking rate (Study 2).

One possible explanation for the lack of difference in likeability is that nucleated glasses did not alter responses to enough individual items that constituted the likeability score to a large enough degree. In support of Study 1's findings on visual appeal, participants in other studies have been observed paying attention to the continuous flow of ascending bubbles during champagne and sparkling wine tasting and noting their visual appeal (Liger-Belair et al., 2008). Similarly, a medium level of beer 'head' foam has been judged the most visually appealing by both males and females (Donadini et al., 2011). The effervescent effect of ascending bubbles and beer 'head' which can be maintained for longer in nucleated glasses appear to be visually appealing to drinkers.

There was no clear evidence for a difference in any of the five individual questionnaire items that constituted the likeability factor in Study 2. A possible explanation could be the difference in perceived effect of nucleation in both studies possibly caused by the change in glassware. Participants rated lager in nucleated glasses as being more bubbly / gassy than lager in non-nucleated glasses in Study 1 but not in Study 2. This could be due to the different time spent consuming beverages in both studies (i.e., 5 minutes in Study 1, average 17 mins in Study 2). The effect of nucleation does diminish over time; therefore participants in Study 2 would have observed the lager being less bubbly / gassy in the nucleated condition for a longer period of time than participants in Study 1 even though the

questionnaire item was presented to participants the same amount of time after each drink was consumed in both studies.

The perceived increase in visual appeal and refreshment in nucleated glasses in Study 1 did not lead to a difference in volume consumed. It is possible that a difference in these measures would not alter consumption in a 5-minute period but may affect consumption over a longer period of time but this was not borne out in Study 2. It has been suggested that the intention of nucleating glassware is to replenish and maintain the head of foam during the consumption of beer (Quain, 2007). It is plausible that the nucleating of glassware is primarily focused at improving the drinking experience of lager, which we saw some evidence for in Study 1, while not explicitly attempting to change how the product is consumed. This is a potential explanation for the lack of a meaningful difference in volume consumed in Study 1 or drinking rate in Study 2.

Some limitations should be considered when interpreting these findings. First, in Study 2, the experimental manipulation may not have had the planned effect of altering nucleation. We can only infer this from the fact that there was little difference in the perception of how bubbly / gassy lagers were in the two glasses, and nucleation was not directly measured. However, results may not represent the true influence of nucleation on drinking rate. Given that the ratings were taken at different timepoints, it may be that any effects of nucleation dissipate over time, and therefore the null finding in Study 2 may reflect this. As we did not take a “bubbly / gassy” rating at the time of serving in Study 2, we cannot determine this in the current study. Future studies could address this by taking repeated measures across the drinking period. Second, both studies were carried out in a laboratory setting and findings may not generalise to naturalistic environments. Finally, the likeability questionnaire used in Study 1 was not a validated measure of likeability of lager and its construct validity is unknown.

In conclusion, there was no meaningful difference in overall likeability of lager consumed from nucleated and non-nucleated glasses in either study. In Study 1, lager in

nucleated glasses was rated as more visually appealing and refreshing than lager in non-nucleated glasses, however this was not replicated in Study 2 with pint sized glasses. Further research should investigate the replicability of these effects. Nucleated glasses appear to have no meaningful effect on the consumption of lager in terms of amount of volume consumed or drinking rate. Based on these findings, nucleation does not appear to have potential as a target for public health interventions. However, future research should investigate the effect of nucleated glasses on the drinking rate of alcoholic beverages over longer drinking periods and across multiple drinks and determine if the null findings are replicated across studies.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

Author Contributions

Designed the studies: DMT, OMM, ASA, MH, MRM. Collected the data: DMT. Data analyses: All authors. Drafted the initial manuscript: DMT. Manuscript revision: All authors. All authors read and approved the final manuscript.

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Supplementary Material

Table 1. Differences in likeability of lager, aspects of the lager drinking experience and volume of lager consumed between nucleated and non-nucleated conditions (Study 1).

	Full sample (*n* = 116)		**Outliers excluded (*n* = 114)**	
	Nuc Mean (SD)	Nonnuc Mean (SD)	Nuc Mean (SD)	Nonnuc Mean (SD)
Total (Likeability) Score	63.2 (13.9)	62.5 (14.0)	63.8 (13.0)	63.1 (13.4)
Likeability sub-scales:				
Visual Appeal	73.6 (17.9)	64.3 (20.0)	74.2 (17.1)	64.0 (20.0)
Enjoyment	70.0 (17.9)	67.9 (18.3)	70.5 (17.3)	68.2 (18.0)
Refreshment	70.9 (16.8)	67.6 (18.7)	71.5 (16.0)	68.0 (18.2)
Tastiness	61.9 (20.1)	61.6 (19.9)	62.4 (19.5)	62.0 (19.3)
Likelihood to Buy	62.8 (24.3)	62.9 (22.3)	63.4 (23.8)	63.4 (21.7)
Other items:				
Bubbly / gassy	72.4 (20.1)	58.5 (23.6)	72.4 (20.1)	58.3 (23.7)
Volume Consumed (ml)	183.5 (75.5)	183.1 (75.6)	184.7 (74.7)	184.0 (75.5)

Nuc = Nucleated condition. Non-nuc = Non-nucleated condition. SD = Standard Deviation.

Table 2. Effect of nucleation on total drinking time (min:sec/0.6; Study 2).

	Mean drinking time	
	Nucleated (SD)	Non-nucleated (SD)
Full sample (n = 160)	18.2 (8.7)	16.7 (7.2)
Outliers excluded (n = 155)	16.9 (6.9)	16.3 (6.3)

SD = Standard Deviation.

Table 3. Effect of nucleation on post-drinking alcohol craving and mood (Study 2).

		Nucleated (SD)		**Non-nucleated (SD)**	
		TP 1	TP 2	TP 1	TP 2
Full sample (n = 160)	AUQ	2.4 (1.1)	2.6 (1.2)	2.2 (0.9)	2.5 (0.9)
	PANAS positive	28.1 (5.8)	26.3 (8.3)	26.9 (7.6)	26.1 (8.1)
	PANAS negative	12.3 (3.3)	11.3 (2.1)	12.5 (3.0)	11.8 (3.1)
Outliers excluded (n = 155)	AUQ	2.4 (1.1)	2.6 (1.2)	2.2 (0.9)	2.6 (0.9)
	PANAS positive	28.2 (5.9)	26.5 (8.4)	26.8 (7.6)	26.2 (8.1)
	PANAS negative	12.3 (3.3)	11.3 (2.1)	12.5 (3.0)	11.8 (3.1)

SD = Standard Deviation. TP = Timepoint.

Table 4. Differences in likeability of lager and aspects of the lager drinking experience between nucleated and non-nucleated conditions (Study 2).

	Full sample (*n* = 160)		**Outliers excluded (*n* = 155)**	
	Nuc Mean (SD) *n* = 80	Nonnuc Mean (SD) *n* = 80	Nuc Mean (SD) *n* = 76	Nonnuc Mean (SD) *n* = 79
Total (Likeability) Score	62.8 (19.3)	63.5 (18.5)	63.7 (19.1)	63.8 (18.4)
Likeability sub-scales:				
Visual Appeal	63.3 (22.3)	65.0 (21.7)	64.6 (21.9)	64.9 (21.8)
Enjoyment	63.1 (22.5)	65.3 (21.3)	64.2 (21.9)	65.7 (21.1)
Refreshment	65.3 (20.7)	68.5 (17.8)	65.5 (21.1)	68.9 (17.5)
Tastiness	60.8 (21.1)	59.6 (21.3)	61.4 (21.1)	60.0 (21.1)
Likelihood to Buy	61.4 (22.8)	59.1 (24.9)	62.6 (21.9)	59.5 (24.7)
Other items:				
Bubbly / gassy	70.5 (18.6)	71.4 (18.6)	70.8 (18.9)	71.1 (18.7)

Nuc = Nucleated condition. Nonnuc = Non-nucleated condition. SD = Standard Deviation.