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1 **Quality assurance and halal control points for the food industry**

2
3

4 **Introduction**

5 Islam has outlined the rules and regulations for food preparation which suggest the
6 source, process and people should conform to the principles of Islam faith (Samori *et*
7 *al.*, 2014) and covers the aspects of nurturing, slaughtering, storage, display,
8 preparation, hygiene and sanitation. Halal (lawful) foods are free from any
9 components that Muslims are prohibited from consuming. Most foods are halal except
10 those that have been specifically prohibited by Qur’ānic guidance (Qur’an, 2:168,
11 cited in Chandia, 2015) and the Sunnah (the life, actions and teachings of the Prophet
12 Muhammad [Peace be upon him (PBUH)]) Riaz and Chaudry, 2004a). In addition, the
13 Qur’ān verses regarding eating and food are “Toyyiban” – an Arabic word translated
14 as “good or wholesome” (Hashimi *et al.*, 2010).

15 Previous studies on understanding of halal concepts had been conducted
16 among general Muslim consumers (Ambali and Bakar, 2014), respondents from
17 higher education institutions (Yusuf and Ab Yajid, 2016), British Muslims (Jamal and
18 Sharifuddin, 2015) and non-Muslims (Mathew *et al.*, 2014). For Muslim consumers,
19 halal food and drinks means products that meet the requirements as laid down by the
20 Shariah law whereas for a non-Muslim consumer, it represents hygiene, cleanliness,
21 quality and the safety of the product (Ambali and Bakar, 2014; Mathew *et al.*, 2014).

22 Hygiene control and sanitation are the top priorities in the manufacturing and
23 distribution of food products. The effectiveness of sanitation procedures had been
24 evaluated using immediate visual assessments or microbiological methods such as
25 hygiene swabs or agar contact plates (Griffith *et al.*, 2000). Rapid hygiene monitoring
26 methods such as adenosine triphosphate (ATP) bioluminescence are available to
27 provide an estimate of total surface contamination in real time has been well
28 documented (Hawronskyj and Holah, 1997). This technique does not require
29 laboratory and specialized staff and can be used effectively in field conditions
30 (Aycicek *et al.*, 2006).

31 Hazard Analysis and Critical Control Points (HACCPs) concept was designed
32 to prevent microbial, physical and chemical hazards in food for the space missions
33 (Janevska *et al.*, 2010). The HACCP system is a recommended approach to enhance
34 food safety from farm to fork. There are suggestions that it could be used to assure

35 halal compliance (Bonne and Verbeke, 2008; Kohilavani *et al.*, 2012; Kohilavani *et*
36 *al.*, 2013; Riaz and Chaudry, 2004a; van der Spiegel *et al.*, 2012). With the help of
37 HACCP, Halal Control Points (HCPs) can be identified to eliminate potential
38 presence of haram (unlawful) components in the manufacturing of halal food products.
39 Halal Control Points plan can be utilized to ensure both food safety and halal analysis
40 of food products. This is based on the view that safe food and hygienic production is
41 the base for halal production (Riaz and Chaudry, 2004a). Food safety is the assurance
42 that food will not cause harm to the consumer when it is prepared and/or eaten
43 according to its intended use (CAC, 1997). As such, the term halal encompasses
44 cleanliness and hygiene in food preparation because cleanliness is part of religion and
45 Allah (S.W.T.) only permits hygiene, safe and halal foods or products for Muslims
46 consumptions (Ambali and Bakar, 2014). Utensils, equipment and machinery
47 (including all food contact surfaces) must be cleaned, sanitized and untainted by
48 contact with haram materials (Henderson, 2015). For the identification of haram
49 substance, zero tolerance practice is adopted to ensure that the religious requirements
50 are stringently followed (Kohilavani *et al.*, 2013). This study aims to determine the
51 understanding of halal concept among food production workers, evaluate the hygiene
52 and sanitation (via adenosine triphosphate (ATP) swabbing) and to develop a generic
53 Halal Control Point (HCP) Plan for food processing.

54

55 **Methods**

56 *Development of Questionnaires and Interview Questions*

57 A semi-structured questionnaire (with both opened and close-ended questions)
58 (Burgess, 2001) which include demographic profile, understanding and attitude
59 towards halal food sections was designed. Statements such as ‘I understand what is
60 Halal’; ‘Halal focuses on slaughtering only’; ‘Halal focuses on slaughtering and food
61 quality’; ‘Halal food does not contain pork and alcohol’ and ‘Halal food must be
62 prepared by Muslims’ were included to capture a snapshot of understanding of halal
63 concepts among food production workers. In-depth interviews related to the quality
64 assurance and halal practices in food manufacturing plants were conducted among
65 Quality Assurance staff. A pilot sample of 30 participants from a food manufacturing
66 company was carried out. A sample of 30 participants from the population of interest
67 is a reasonable minimum recommendation for a pilot study where the purpose is
68 preliminary survey or scale development (Johanson and Brooks, 2009). Cronbach’s

69 alpha is used as a measure of the reliability (≥ 0.70) of a set of questions in a survey
70 instrument as it can measure the interrelatedness of a set of items (Cronbach, 1951).

71

72 *Sampling*

73 Two hundred respondents were targeted as the minimum sample size to ensure
74 reliability (Yurdugul, 2008). Respondents (ethnic origins and religions were not taken
75 into consideration to reduce biasness) were randomly selected from four different
76 halal food manufacturing plants: Company A (soy sauce), Company B (frozen
77 chicken roll), Company C (oat) and Company D (coffee powder). 150 respondents
78 were from companies A and B and the remaining 50 from firms C and D. Although
79 survey and interviews were conducted among workers from Company A, no
80 swabbing tests were allowed. All organisations had been renamed as A – D to ensure
81 anonymity.

82

83 *Real Time ATP Hygiene Monitoring System and Microbiological Tests*

84 Hygiena's SystemSURE Plus (Hygiena, Camarillo, CA, United States) ATP hygiene
85 monitoring system was used to detect the level of hygiene in workers' and associated
86 food preparation surfaces in the processing plants. Food contact surfaces and workers'
87 hands (from lower palm to each fingertips) were swabbed during production and
88 results were expressed numerically as Relative Light Units (RLU) (Hygiena, 2013).
89 End products were collected from each food processing plants and transported back to
90 the laboratory. Short shelf life product i.e. frozen chicken roll were transported in a
91 carrier box containing ice packs and analyses were performed upon receipt of samples
92 at the laboratory. However, if a laboratory analysis was postponed due to delayed
93 arrival of samples, the samples were refrigerated at 0 – 4°C until examination but
94 were not kept longer than 36 hours (Al Mamun *et al.*, 2013). 25 g of each sample
95 were homogenised in 1% buffered peptone water in a Stomacher 400 Circulator
96 (Seward, UK) blender for 2 minutes. Following homogenization, all samples were
97 tested for total plate count.

98

99 *Halal Control Points (HCPs)*

100 In this study, HACCP and Halal Critical Control Points decision tree (Kohilavani *et*
101 *al.*, 2013; MS 1500: 2009) were adapted to identify and eliminate potential presence
102 of haram components (Figure 1).

103

104 **Figure 1.** Decision tree to identify Halal Critical Control Points (HCCPs) in
105 ingredients and process controls (Kohilavani *et al.*, 2013; MS 1500: 2009)

106

107 **Results and Discussion**

108 *Validation of Questionnaire*

109 The pilot test questionnaires were analyzed and the value of Cronbach's alpha was
110 0.801. The higher the Cronbach's alpha coefficient is, the more correlated the items
111 are within the relevant variable which theoretically should be higher than 0.700
112 (Pallant, 2005).

113

114 *Demographics*

115 Majority of the participants came from the age group of 31 to 40 years (40.00%)
116 (Table 1). According to the Department of Statistics Malaysia (2015), the percentage
117 of employed persons in 2014 showed that 76.20% of the persons employed were from
118 the age group of 25 to 54 years old whereas minority (8.20%) were employees from
119 age 55 to 64 years old. Furthermore, majority of the respondents (87%) had
120 completed secondary education whilst 19% studied at upper secondary schools and
121 above.

122

123 **Table 1.** Demographics of food production workers (N = 200)

124

125 *Understanding and Attitude towards Halal Food Products*

126 The respondents' understanding of halal principles is important in providing an
127 insight into Malaysian consumers' attitudes toward halal products. In this case, 77
128 respondents (38.50%) claimed that they understand the concept of halal. In contrast, a
129 minority of them claimed that halal foods must only be prepared by Muslims ($\chi^2 =$
130 50.95; $df = 4$; $P < 0.05$) (Table 2). Previous findings suggested that consumers
131 generally perceive pork and alcohol to be haram (Salman and Siddiqui, 2011).
132 Although participants have various responses towards this statement, these do not
133 indicate that they have a poor understanding or misconception towards the concept of
134 halal. (Nawai *et al.*, 2007). In fact halal has now become a universal concept as

135 demonstrated in other similar studies (Ambali and Bakar, 2014; Henderson, 2015;
136 Mohd Shariff and Abd Lah, 2014).

137

138 **Table 2.** Participants' single response towards the concept of halal (N=200)

139

140 Based on Table 3, 76.5% of the respondents (regardless of religion)
141 demonstrated a positive attitude towards halal food products. Religious beliefs, food
142 safety, animal welfare, environmentally friendly, age, education level and area of
143 residence are significant determinants of the consumers' attitude towards
144 understanding and awareness of halal principles and halal food products (Rezai *et al.*,
145 2010). However, the behaviors of Muslims consumers are largely predisposed by their
146 Islamic ideology (Salman and Siddiqui, 2011).

147

148 **Table 3.** Attitude of respondents towards halal food products (N=200)

149

150 *ATP Swabbing Tests*

151

152 **Table 4.** Adenosine Triphosphate (ATP) swabbing tests (N =12)

153

154 Company B revealed the highest average RLUs (233.5 ± 2.1) due to the presence of
155 food debris and this is particularly related to the chemical composition of the organic
156 residues present (Moore and Griffith, 2002). Investigation conducted in vegetable
157 processing plant revealed that the surface of chopping board possessed 209 RLU
158 (Kuisma *et al.*, 2014). In contrast, the lowest average RLUs were recorded in
159 Company C. This might be due to the implementation of HACCP and International
160 Organisation for Standardisation (ISO) 22000 Food Safety Management Systems in
161 the manufacturing plant. Food production workers' left and right hands (from lower
162 palm to each fingertips) were swabbed as these areas can provide a suitable and
163 sufficient surface area for swabbing (Yaambut *et al.*, 2016). The highest mean RLU
164 (96.5 ± 2.1) was recorded in workers from Company D. It is probable that the daily
165 cleaning is not following the standard procedures. Similar ATP swabs were conducted
166 domestically by Larson *et al.* (2003) with acceptable values (2.6 ± 0.8 RLU) (Larson
167 *et al.*, 2003) while Sudheesh *et al.* (2013) reported that all tested food contact surfaces
168 failed the sanitation quality test with readings as high as 100,000 RLU. Aprons were

169 provided for food production workers which were changed on a daily basis. The
 170 highest mean RLU was found among workers from Company B. The lowest mean
 171 RLU reading was from Company C which has an integrated automated system to
 172 facilitate mechanical production of goods, and workers' aprons were less likely to be
 173 contaminated with food residues. In another similar study, Worsfold and Griffith
 174 (2001) found 96469.00 RLU on aprons and the ATP might had be derived from dead
 175 microorganisms, food residues or hand ATP. Primary or secondary packaging
 176 materials (plastic) were also swabbed. In this case, the recorded RLU readings for
 177 three companies were same, which was 0 RLU.

178

179 *Halal Control Points (HCPs)*

180 Hazard Analysis and Critical Control Points (HACCPs) is a Food Safety Management
 181 System (Al-Kandari and Jukes, 2011) which is widely acknowledged as the best
 182 method of assuring product safety whilst becoming internationally recognized as a
 183 tool for controlling food borne safety hazards (Khandke and Mayes, 1998; Wallace *et*
 184 *al.*, 2005). In this study, HACCP was adapted with Halal Control Points (HCPs) to
 185 identify and eliminate potential presence of haram components. Based on Kohilavani
 186 *et al.* (2013) decision tree, survey and the interview results from the four food
 187 manufacturing plants, four specific HCPs plans were developed (SeeAppendix for
 188 Supplementary File Tables 1-4). The supplementary tables provide a halal analysis
 189 and justification for inclusion of the HCPs. This concept is similar to hazard analysis
 190 in HACCP.

191

192 Based on the four specific HCPs plans generated, a generic HCPs Plan was developed
 193 (Figure 2). It is useful as it can be used as a guideline in halal food industries with the
 194 purpose of identifying the possible sources of haram contamination.

195

196 **Figure 2.** Generic Halal Control Points for food industries

197

198 *HCP 1: Halal Certification*

199 When importing raw materials from foreign countries, the manufacturer sends
 200 representative to the supplier's site to conduct audit. This includes inspecting the
 201 implementation of halal practices in the premises, quality of the raw materials and

202 halal certification. Today, many Muslims countries require food products imported to
203 their countries be certified halal (van der Spiegel *et al.*, 2012). In order to get halal
204 certification, inspection of the facility, review of sanitation, ingredients and labels and
205 training the company personnel are important (Riaz and Chaudry, 2004b).

206

207 *HCP2: Equipment*

208 For the company producing non-meat products, it is sufficient to clean equipment and
209 determine cleanliness by visual observation. If food premises producing halal food
210 carry out haram operations, it is required to perform a mandatory ritual cleansing
211 (Man and Sazili, 2010). Besides, chemicals used for cleaning should be screened to
212 avoid animal fat origin (Riaz and Chaudry, 2004a) and the brushes should be halal
213 certified as it can be made out of pigs' hair (Fischer, 2015).

214

215 *HCP3: Raw materials/ingredients*

216 The halal status of ingredients derived from plant origins is rarely an issue except it is
217 from animals (Riaz and Chaudry, 2004a). Flavours and flavourings contain several
218 ingredients that can be derived from microorganisms, plants, minerals, petroleum,
219 animals and synthetic sources. So, the manufacturer has to make sure that any
220 flavours, proprietary mixes or secret formulas are halal and free from doubtful
221 materials (Riaz and Chaudry, 2004a).

222

223 *HCP4: Transportation and storage*

224 Often, the manufacturer takes charge of the shipping and storage condition or they
225 rely on the vehicles of buyers in the distribution of goods. The vehicles used to
226 transport goods must be cleansed thoroughly and avoided from shipping food
227 products which could emit pungent odor such as onion or garlic. The storage
228 condition should also be inspected by the related staff to ensure the freshness of the
229 food products. During transportation, halal foods must be handled properly to avoid
230 cross-contamination with haram products.

231

232 *Microbiological Analysis*

233 No microorganisms were detected in food samples such as frozen chicken roll, oat
234 and coffee powder but the TPC found in soy sauce was $4.8 \pm 5.1 \log \text{CFU/mL}$. Yan *et*
235 *al.* (2013) conducted an enumeration of microbiota present during koji-making in soy

236 sauce production found that the total mesophilic aerobic bacteria (TMAB) was 8.8 log
 237 CFU/g. In this study, the microbial load was much lower compared to Yan *et al.*
 238 (2013) which may be attributed to the heat treatment applied on the soy sauce after
 239 passing through the koji-making process. Soy sauce was found to initiate the growth
 240 of purple mucoid colonies on Eosin and Methylene Blue (EMB) Agar. The absence of
 241 green metallic sheen suggested that *Escherichia coli* was absent as Eosin methylene
 242 blue agar provides a rapid and accurate method to identify *Escherichia coli* (Leininger
 243 *et al.*, 2001; Macfadden, 1985) Primary screening test was performed and the
 244 suspected colonies were from the family of Enterobacteriaceae (Singh *et al.*, 2015).
 245 Previous studies revealed that nine species belonging to the family Enterobacteriaceae
 246 were identified in the fermentation of inyu (Wei *et al.*, 2013) and koji (Yan *et al.*,
 247 2013).

248

249 *Conclusion*

250 The findings indicated that food production workers in general demonstrated an
 251 understanding and positive attitude towards halal food products. In terms of hygiene
 252 and sanitation of the manufacturing plants, the ATP swabbing tests of food contact
 253 surfaces (tabletops) revealed that only two companies passed the swabbing tests (≤ 10
 254 RLU). The ATP swabbing tests for all workers' hands and aprons did not meet the
 255 hygiene requirements (> 30 RLU). Based on the interviews conducted with quality
 256 control staff, Halal Control Points (HCPs) were identified in the manufacturing
 257 process of food products, and one generic HCPs plan and four specific HCP plans
 258 were developed for the manufacturing process of halal food products for each food
 259 company.

260

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- 413 Appendix
- 414 Insert Supplementary file tables 1-4 (four tables)

Table 1. Demographics of food production workers (N = 200)

Demographic items	N (%)
Age	
≤ 20	None
21-30	73 (37)
31-40	80 (40)
41-50	36 (18)
≥ 51	11 (6)
Position	
Manager	4 (2)
Production worker	140 (70)
Quality assurance/executive	9 (5)
Research and development executive	8 (4)
Supervisor	9 (5)
Others	30 (15)
Number of years working in food industry	
≤ 5	103 (52)
6-10	59 (30)
11-20	33(17)
≥ 21	5 (3)
Academic qualification	
Primary level	None
Lower secondary level	40 (20)
Secondary level (O levels)	87 (44)
Upper secondary level (A levels)	2 (1)
Diploma/Degree/Master/PhD	36 (18)
Others	35 (18)

Notes: N represents the number of respondents; (%) represents their share in the sample.

Table 2. Participants' response towards halal concepts (N=200)

Understanding of halal concepts:	<i>N</i> (%)
I understand what is Halal	77 (39)
Halal focuses on slaughtering only	24 (12)
Halal focuses on slaughtering and food quality	32 (16)
Halal foods do not contain pork and alcohol	45 (23)
Halal foods must be prepared by Muslims	22 (11)

Notes: N represents the number of respondents; (%) represents their share in the sample. Chi-square test has been performed ($\chi^2 = 50.95$) and all statements are significantly different at the level of 5%.

Table 3. Attitude of respondents towards halal food products (N=200)

Statement	N (%)
I emphasized the halal status of food products that I purchased ^a	
Strongly disagree	0
Disagree	0
Neither agree nor disagree	47 (24)
Agree	95 (48)
Strongly agree	58 (29)
Religious obligation is a major concern of mine when purchasing food products ^b	
Strongly disagree	0
Disagree	0
Neutral	54 (27)
Agree	97 (49)
Strongly agree	49 (25)
Halal principle is related to hygiene and food safety ^c	
Strongly disagree	0
Disagree	0
Neutral	50 (25)
Agree	93 (47)
Strongly agree	57 (29)
Knowing how halal food is produced or processed is very important ^d	
Strongly disagree	0
Disagree	0
Neutral	55 (28)
Agree	100 (50)
Strongly agree	45 (23)

Notes: N represents the number of respondents; (%) represents their share in the sample (five-point Likert scale: 1 = “strongly disagree”, 3 = “neutral”, 5 = “strongly agree”). Chi-square test has been performed to compare the statements of respondents towards halal food products. Items denoted with superscripts represent the χ^2 values (a = 18.97; b = 20.89; c = 15.97; d = 25.75) and all statements are significantly different at the level of 5%.

Table 4. Adenosine Triphosphate (ATP) swabbing tests (N =12)

Area being swabbed	Company (Reflective Light Unit [RLUs] of contact surfaces)			
	A (soy sauce)	B (chicken roll)	C (oat)	D (coffee powder)
Preparation tables	-	Fail (233.5 ± 2.1)	Pass (1.0 ± 0)	Pass (2.5 ± 0.7)
Workers' hands (left and right hands – swabbed from lower palm to each fingertips)	-	Fail (82.0 ± 2.8)	Fail (73.0 ± 1.4)	Fail (96.5 ± 2.1)
Workers' aprons	-	Fail (84.5 ± 0.7)	Fail (56.5 ± 2.1)	Fail (67.0 ± 1.4)
Packaging materials	-	Pass (0)	Pass (0)	Pass (0)

Notes: N represents the number of swab samples. The calculated values are expressed as mean values of triplicate samples ± standard deviation. Swabbing tests were not permitted in Company A. Pass: Any score of 10.00 RLU or less; Caution: Scores from 11.00 to 30.00 RLU; Fail: Any score greater than 30.00 RLU

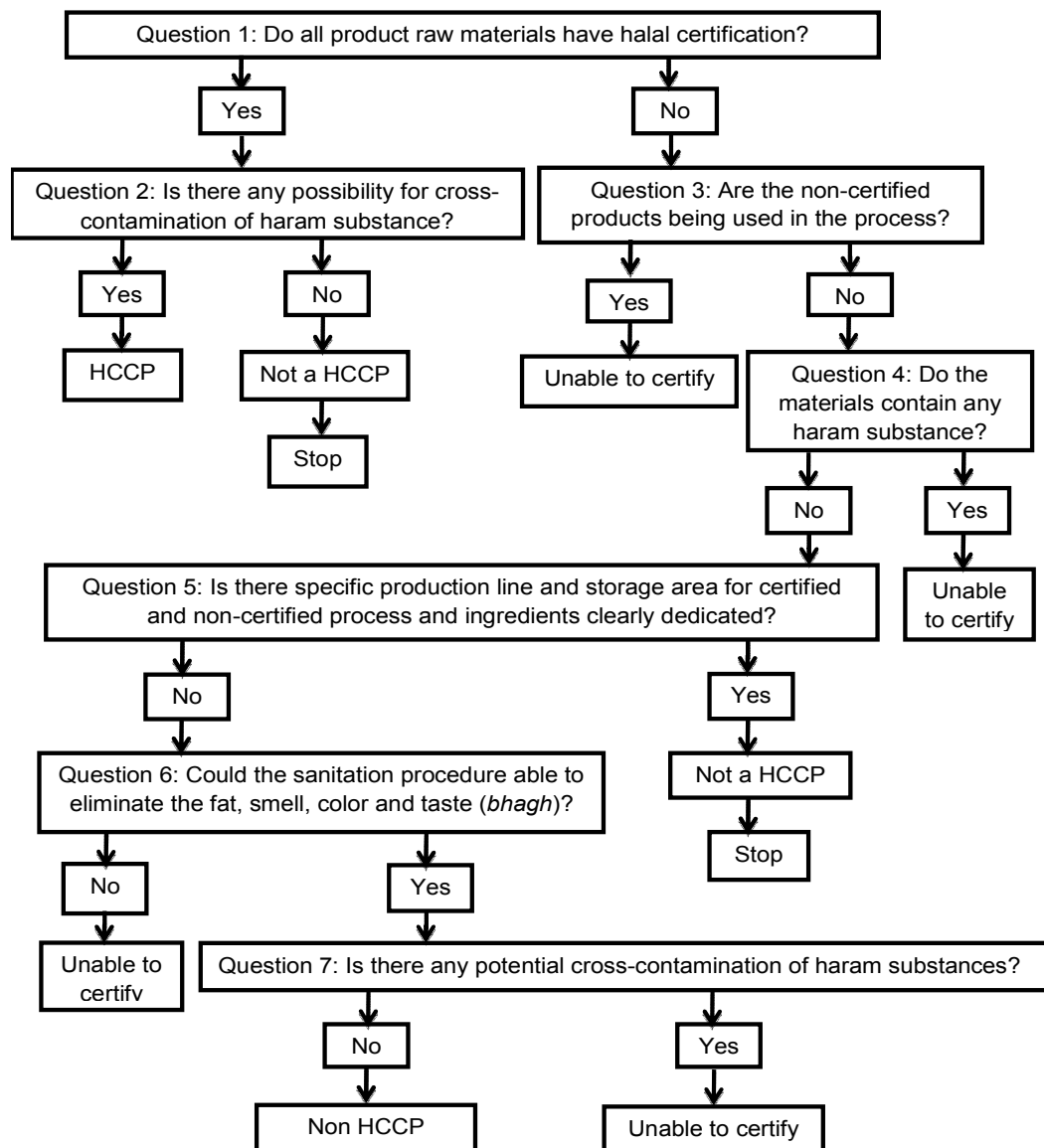


Figure 1. Decision tree to identify Halal Critical Control Points (HCCPs) in ingredients and process controls (Kohilavani *et al.*, 2013; MS 1500: 2009)

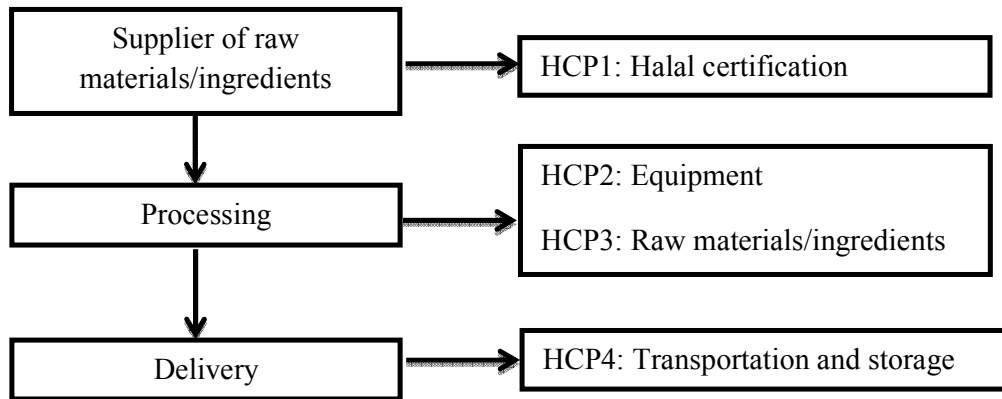


Figure 2. Generic Halal Control Points (HCPs) for food industries (See Supplementary Files Tables 1 – 4 for halal analysis and identification of HCPs)

Supplementary File Table 1. Halal analysis and identification of Halal Control Points (HCPs) in production of soy sauce

Process steps	Halal Control Points (HCPs)	Justifications	Preventive measures
Selection	HCP 1	Potential for transport or storage contamination with non-halal products	Suppliers to provide halal certifications or conduct suppliers' second party audit to verify storage of soy beans and incoming goods check
Koji / Moromi	HCP 2	Potential for mixing with non-halal products such as alcohol to enhance the flavour and taste of soy sauce	Quality control performed by related trained staff in halal certification
Refined soya sauce	HCP 3	Potential of entrance of non-halal products into the final product	Quality control performed by related trained staff in halal certification
Delivery	HCP 4	Potential for transport contamination with non-halal products	Transports were cleaned and inspected by related trained staff in halal certification

Supplementary File Table 2. Halal analysis and identification of Halal Control Points (HCPs) in production of frozen chicken roll

Process steps	Halal Control Points (HCPs)	Justifications	Preventive measures
Receipt of halal chicken	HCP 1	Potential for transport or storage contamination with non-halal products	Supplier to provide halal certification
Production	HCP 2	Potential for mixing with non-halal ingredients such as lard which has been commonly used to replace oil	Quality control performed by related trained staff in halal certification
Delivery	HCP 3	Potential for transport contamination with non-halal products	Transports were cleaned and inspected by related trained staff in halal certification

Supplementary File Table 3. Halal analysis and identification of Halal Control Points (HCPs) in production of oats

Process steps	Halal Control Points (HCPs)	Justifications	Preventive measures
Receiving	HCP 1	Potential for transport or storage contamination with non-halal products	Supplier to provide halal certification or conduct supplier second party audit to verify storage of oat and incoming goods check
Kilning	HCP 2	Potential for mixing with non-halal products (cheaper raw materials and ingredients)	Quality control performed by related trained staff in halal certification
Delivery	HCP 3	Potential for transport contamination with non-halal products	Transports were cleaned and inspected by related trained staff in halal certification

Supplementary File Table 4. Halal analysis and identification of Halal Control Points (HCPs) in production of coffee powder

Process steps	Halal Control Points (HCPs)	Justifications	Preventive measures
Receiving	HCP 1	Potential for transport or storage contamination with non-halal products	Supplier to provide halal certification
Roasting 1 / 2	HCP 2	Potential for mixing with non-halal products (cheaper raw materials and ingredients) in the open roaster	Quality control performed by related trained staff in halal certification
Delivery	HCP 3	Potential for transport contamination with non-halal products	Transports were cleaned and inspected by related trained staff in halal certification