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INNOVATION READINESS ASSESSMENT TOWARD RESEARCH COMMERCIALIZATION: CASE OF SURFACTANTS FOR FOOD PROCESSING

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Abstract: Determining the readiness of research toward commercialization becomes significant issues encountered by the institution working on research, innovation and technology development. Particularly in food processing area, the issue is much more involving other aspects aside from technological matter, hence, an assessment tool should be consider these aspects altogether to capture integrated perspective. This study explored the use of Innovation Readiness Level to measures the maturity of research from the perspective of technology, market, organization, partnership and risk. Case of surfactant researches in the Research Center for Chemistry, Indonesian Institute of Sciences will be deployed as examples of study. According to the assessment, it has been obtained the surfactant recommended for further development towards commercialization of R & D results for food processing, i.e. Glycerol Mono Stearate (GMS), which has reached the level of IRL 3. This finding resulted some implications for improvements strategies to foster the research toward commercialization.

Keywords: Food Processing, Innovation Readiness Level, R&D Institution, Surfactant, Technology Assessment.

INTRODUCTION

Increasing interest in innovation capabilities indicates that innovation could be recognized as a key success factors in an increasingly competitive global economy (Alegre et al., 2005; Day et al., 2000).

However, successful and sustained innovation presents challenges rooted in technological uncertainties, ambiguous market signals and embryonic competitive structure (Forsman, 2009).

Some scholars have argued that the successful innovation is highly dependent on how the systematic that organizations use to develop new and improved products, services, production systems and businesses process (Wychal et al., 2011). This includes the system for assessing innovation readiness, developing and testing metrics to measure it.

In the food technology field, breakthrough of innovation occurs slowly and cautiously in the food and beverages industry, and it occurs continuosly in R&D center for ingredient and equipment manufacturers (Fusaro, 2013). There are many factors should be considered for a technology to enter into commercialization, such as market trend and opportunity (Ministry of Agriculture Canada, 2013).

In addition, as product life cycle is shorther in fierce competition, industry should boost their research to make innovation. Therefore, assessment for readiness of emerging technology should also cope with these challenges.

Surfactants (surface active agents), are compounds that decrease the surface tension (or interfacial tension) between liquid-liquid or between liquid-solid. It consists of a non-polar hydrophobic portion, usually a straight or branched hydrocarbon or fluorocarbon chain containing 8–18 carbon atoms, which is attached to a polar or ionic portion (hydrophilic) (Tadros, 2005).

Surfactants may has functions as detergents, emulsifiers, wetting agents, foaming agents, and dispersants. At the Research Center for Chemistry (RCC), Indonesian Institute of Sciences (LIPI), surfactant technologies have been developed for many sectors, including food industry, adjuvant poultry vaccines, textiles and petroleum fields.

There are many types and application of surfactants, hence, it was difficult to predict the direction for technology development (Aiman, 1998). Fig. 1 depicted this problem in general, which illustrates there are many potential application of surfactants.

In addition, in table 1, it can be seen that there are a number of potential application for food processing. As for such situation, assessing the existing technology status will provide significant benefit for further development and commercialization of surfactant.

Some tools or measurement techniques have been studied and introduced by scholars for the assessment, such as Innovation Readiness Level (IRL), Manufacturing Readiness Level (MRL), and Technology Readiness Level.

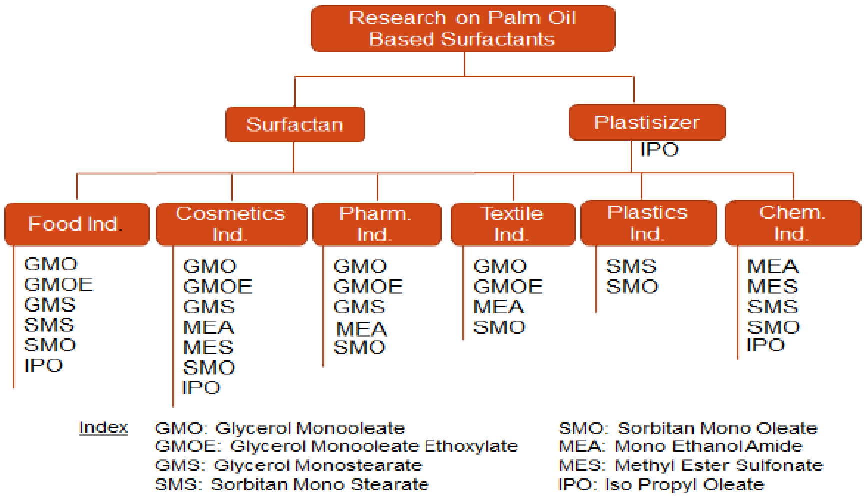

Fig. 1

Potential application of surfactant researches developed at RCC LIPI (Fitriady et al., 2015).

Table 1

Surfactants potential application for foods

No.	Surfactants	Application for Foods
1	GMS	Emulsifier, thickening agent, anticaking agent, preservative agent
2.	SMS	Dispertion agent (milk powder), rehidration agent (yiest), emulsifier (food)
3.	GMO	Dispertion agent (milk powder), emulsifier
4.	GMOE	Dispertion agent (milk powder), emulsifier
5.	SMO	Sweeting agent, food additive, filter (medication), emulsifier
6.	IPO	Indirect food additives, as an adjuvant (to improve lubricity) in mineral oil lubricants (U.S. Food & Drug Administration, 2017)

Innovation Readiness Level (IRL) is a tool that shows the development a technology over its life cycle toward innovation (Lan, 2006). IRL consist of 6 level of "C" to represent the technology stages by considering 5 aspects: technology, market, organization, partnership and risk (Lan et al., 2010). It was also developed by accommodating previous theory on TRL, System Readiness Level (SRL), etc.

This study aims to assess the recent progress of surfactant technologies developed for food processing at RCC LIPI. IRL will be utilized to support the study, particularly to demonstrate the application of IRL to classify the achievement of each type of surfactant based on provided scales (1-6). As result, one or more prospective surfactants can be proposed as recommendation for further development and commercialization.

The scope of study will be limited to surfactant researches at the RCC LIPI. Specifically, the study will be focused to access 6 (six) selected surfactants which are technically and economically prospected to have further development by collaborating with other partner such as university, industry and community.

FRAMEWORK OF STUDY

Innovation Readiness Level (IRL)

The concept of IRL is based on six "C" model which represents a comprehensive lifecycle phase of innovation, i.e. Concept, Component, Completion, Chasm, Competition and Changeover/ closedown. Each phase is projected upon five aspects including technology, market, organization, partnership and risk (Lan et al., 2010). Further development of the concept of IRL has been also studied by Lee, et al. (2011), which acccommodates innovation theories such as product life cycle, system readiness levels, the market adoption model, and technology readiness level. The overall framework for assessing IRL is depicted in Table 2.

IRL and Technology Readiness Level (TRL)

TRL measurement was first developed by NASA in 1974 with 7 levels and expanded to 9 levels in 1990s which has widely accepted around the world (Banke, 2010).

Aside from NASA and U.S. Departement of Defense, this tool has been implemented in various field and organization, such as European Space Agency, European Commission, Oil and Gas Industry, U.S. Department of Energy, U.S. Department of Health, and European Association of Research and Technology Organisations (EARTO).

In Indonesia, TRL was adopted in 2005 by the Agency for the Assessment and Application of Technology (BPPT) and socialized by Ministry of Research and Technology in 2011 to help the diffusion and incubation program of technopreneur in Indonesia (Arwanto & Prayitno, 2013).

The ministry has organized research grant allocated to applicant based on their research achievements which can be indicated by TRL. It is expected that a lot of sophisticated technology will arise and sustain as it has been tested earlier.

Based on the documents or the results of research, development and engineering data, TRL is measured by providing marks on the provided spreadsheet table. The terms and conditions checklist for every level of TRL should be agreed or become a consensus beforehand. Measurement starts by giving a mark on the checklist requirements and conditions of the lowest TRL 1 (Prayitno, 2008; Prayitno et al., 2012).

Table 2

Framework for Assessing IRL (Lan, Probert, & Phaal, 2010)

	Technological Development			Market Evolution		
IRL Key Aspects	IRL 1 Concept	IRL 2 Components	IRL 3 Completion	IRL 4 Chasm	IRL 5 Competition	IRL 6 Changeover/ Closedown
Techno-logy	Potential improvements of existing technologies or products identified and reported; Technology feasibility confirmed	Individual components tested; Prototypes demonstrated; IP protected	Actual system demonstrated; External test completed; IP protected; Technology/ product documented; Launch	Expertise formed; General availability to the market; Aftersales support	Lower R&D activities; Technology maintenance enabled; Technological service provided	Re-innovate or exit
Market	Market research conducted; Working with leading customers; Customer needs and demands observed	End-customer identified; Detailed market launch plan issued	Specific needs and requirements of customers known; Market segment, size and share predicted; Pricing & Launching issued	Positioning in the market; Business model established; Customer intimate marketing (feedback); Competitors identified; Partnership is an option to break into market	Products differentiated; Service and solutions provided; Periodical review conducted; Business model refined; Partnership is an option to compete	Declining market confirmed; Market research conducted for approval to reinnovate or exit
Organi-zation	Strategy fit confirmed;	Business analysed and plan issued; Key individuals involved	Formalising organisation	Formal organisation established	Improved effectiveness and cooperation; Necessary restructure made	
Partner-ship	Potential partners identified	Partners selected; Calibration established	Partnership formally established	Cooperation within dynamic network; On-going management		Cease partnership
Risk	Technology risk considered	Technological risk assessed (alternative solution considered); Market risk assessed; Organisational risk considered (investment plan initiated and investment started)	Technological risk assessed; Organisational risk assessed (profit predicted; large investment issued)	Organisational risk periodically assessed (especially financial indicators)	Organisational risk periodically assessed (especially financial indicators)	Re-innovate or exit considered; Changeover or closedown plan issued

When all of the terms and conditions for TRL 1 are fulfilled, it should be followed by a checklist of requirements and conditions for TRL 2 and so on to a higher level of TRL (Nolte, 2005). The definition of 'fulfilled' included that it must be agreed or to be the consensus and its value normally ranges between 75 to 100%.

TRL of highest level that met the requirements and conditions, indicate the level of achievement of the measured technology (Taufik, 2003). This size gives the snapshot on the status of technology maturity at a certain time. When TRL measurement is repeated at specific time periods, the results of TRL can be used to evaluate the historical process of what has been done in a technology program and achievement of readiness / maturity of the technology.

Technology Readiness Level can be utilized to measure the first key aspect of Innovation Readiness Level, i.e. Technology aspect. An integration of TRL into IRL has also been introduced (Fig. 2), implying that after completing TRL level 9, technology will finish IRL 3 as well (Sutasena, 2014).

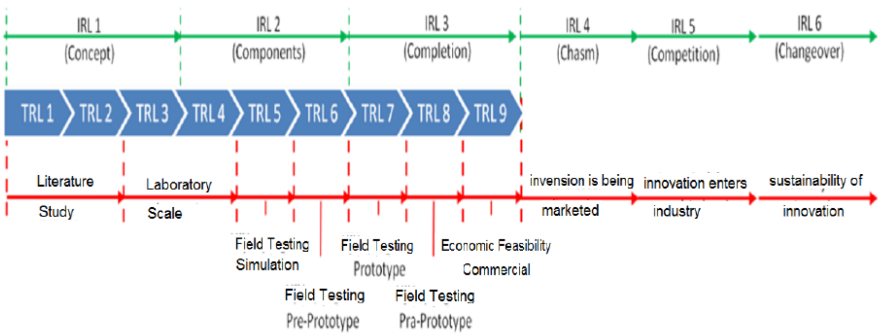

Fig. 2

Integration of Technology Readiness Level and Innovation Readiness Level (Sutasena, 2014).

METHODS

Data collection

The data for this study is collected from the available researches on surfactant at the RCC LIPI. There are a number research on surfactants at RCC LIPI (as listed in Fig.1, while the product sample is depicted in Fig. 3). These data then filtered based on their function to support food processing. Preliminary assessment have been conducted using Technology Readiness Level to obtain some recommended surfactants for further developments (Setiawan & Sulaswatty, 2017). These results then filtered particularly to fit the purpose for food processing.

Fig. 3
Samples of surfactant products developed by researchers of RCC LIPI.

Data Analyses

The collected data is analyzed based on framework of Innovation Readiness Level (Table 2). Analyses was performed using 5 (five) key aspects of IRL in order to determine the level of IRL for each type of surfactants. The result of this assessment was then discussed and verified with the relevant researchers and staffs involved in the related research.

RESULTS AND DISCUSSION

Technology readiness assessment of surfactants for food processing at RCC LIPI

Assessment on technology readiness of surfactants has been conducted in RCC LIPI by using TRL on 12 (twelve) type of surfactants (Setiawan & Sulaswatty, 2017). The assessment was performed toward reseachers involved in the surfactant projects. They were invited to a meeting to assess and verify their responses on TRL meter. This meeting was also attended by Division of Technology Management and Disemination (PDHP) of RCC LIPI, which provided perspective for supporting technology assessment, transfer and commercialization.

For the purpose of this study, 6 of 12 surfactants have been selected, which is suitable for food industry.

The result of the assessment is depicted in Fig. 4. The assessment result shows that the highest TRL score of surfactants is GMS (Glycerol Mono Stearate) which has reached TRL level 7. This is followed by SMS (TRL 4) and then by SMO (TRL 3) and GMOE (TRL3). If this result displayed using IRL perspective, GMS has entered IRL 3, SMS has entered IRL 2, while the others are still in IRL 1.

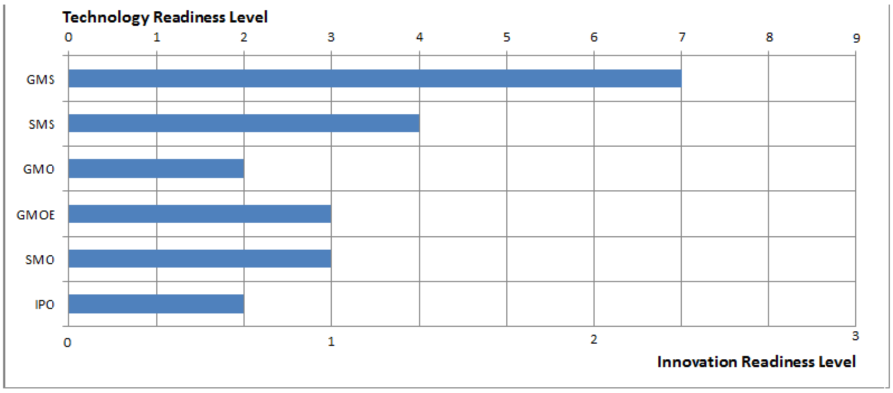

Fig. 4
Assessment on Technology Readiness and Innovation Readiness of Surfactants for Food Processing.

Innovation readiness assessment

1 Technology aspect

Surfactants can be applied for food in form of emulsion, such as oil in water (O/W) emulsion, water in oil (W/O) emulsion and water in oil in water (W/O/W) emulsion (Sharma, 2014).

The application of O/W emulsion e.g. in ice cream mixes, sauces, mayonnaise, creamers, and whippable topping. W/O emulsion exists in food products such as.margarine and butter. W/O/W emulsion is an O/W emulsion which its droplets contain water droplets such as in baked products.

Food products utilizes surfactant properties in some extends. For instances, with its surface active properties, surfactant can be used for foam generation such as in ice cream and baking goods, or foam inhibition such as in sugar beets (Priorr, 1987).

While the dispersion properties of surfactants can be utilized to improve the plasticity of food products, such as in chocolate by reducing its viscosity.

RCC LIPI has developed research on surfactants since 1990s. The initial assessment was conducted based on document reports and publication available at RCC LIPI’s database. The initial finding on the objects of this study are listed below.

· *Glycerol Monostearate* (GMS)

In food processing, GMS is known for its application in baking preparations to add "body" to the food. In 2002, researchers of RCC LIPI has obtained optimal process condition at laboratory for 10 liter production (Hilyati et al., 2000). In 2002-2003 researchers have developed GMS derivated from oil palm at production scale of 500 kg/ batch (Wuryaningsih et al., 2003). Some of results including identified storage time, instrument and facility design and installation, and feasibility study (Center for Innovation LIPI, 2002).

· Sorbitan Mono Stearate (SMS)

The application of SMS in RCC LIPI has been conducted, i.e. in 1999 by evaluating its potential for stabilizer in fruit juice (Sulaswatty et al., 1999).

According to the research, it has been obtained to optimal composition of SMS for pineapple juice, jackfruit juice and watermelon juice. It was also confirmed that in some condition, the application of developed SMS has better result compared to other sorbitant ester available at market such as SMO.

· *Glycerol* Monooleate *(GMO)*

GMO is characterized as a clear amber or pale yellow liquid. It is insoluble in water, slightly soluble in cold alcohol, and soluble in hot alcohol, in oil, in chloroform, in ether, and in petroleum ether (National Academy of Sciences, 1996).

GMO can be used as a moisturizer, emulsifier, and flavoring agent. It also serves as an antifoam in juice processing and as a lipophilic emulsifier for water-in-oil applications. Many forms of glycerol oleate are widely applicable for cosmetics (Cosmetic Ingredient Review Expert Panel, 1986). It is also widely used as an excipient in antibiotics and other drugs.

As Indonesian government has identified downstream industry of oil palm for national development priority, RCC LIPI followed up in 2001 by conducting research on oil palm product derivatives including GMO, GMS, SMO and SMS (Friani et al., 2013). These researches were started from laboratory and scaled up into bench and mini pilot plant.

· *Glycerol Monooleate Ethoxylate* (GMOE)

This palm oil based nonionic surfactant was synthesized in RCC LIPI by reacting glycerol monooleate with ethylene oxide in the prescence of a catalyst, resulting ethoxylated glycerol monooleate which was soluble in water and show potential use as surfactant (Adilina et al., 2007; 2014; 2015).

· *Sorbitan Mono Oleate (SMO)*

SMO is non ionic surfactant with trade name Span 80 (Sondari, 2007). The development of SMO has been conducted using 500 mL stirred batch vacuum reactor in oil bath by esterification process of oleic acid with sorbitol and catalyzed by p-toluene sulfonic acid (Anah, 2007). The GC chromatogram showed that sorbitan monooleate from this experiment has the same with the standard.

· *Iso Propyl Oleat* (IPO)

The development of IPO at RCC LIPI has reached production scale of 50 kg per batch with additional formula variation (Haryono,2006). The formula was tested with comparable result to substitute commercial product. Application for blood bag has also been investigated, resulting business plan and feasibility study embedded.

Aside from researches, the surfactant technology developments has also been registered in form of patents. Table 3 shown the patents achievement related to surfactants by inventor of RCC LIPI.

2. Market aspect

In general, market aspects on surfactants have been studied in RCC LIPI, i.e. by surfactant business plan team (Fitriady et al., 2015). There is a division in RCC LIPI, namely Division of Technology Management and Dissemination, which provides support for conducting feasibility study, market assessment, organization development and research cooperation. For specific purpose, the Director of RCC LIPI has also issued a decree to assemble a team with various background of expertize to perform assessment on research output (Haryono, 2016).

This team performs assessment on research output of RCC LIPI by conducting feasibility study, technology readiness assessment, etc. (therefore, in English somehow the assessment was abbreviated with TERRIFIC- Techno Economic and Research Readiness Implemented for Industry and Community).

Table 3

Patents of Surfactants for Food Processing by inventor of Research Center for Chemistry LIPI

No.	Patent No. (Date of Submission)	Title	Inventor	Related Surfactant
1.	P00200700238 (22 May 2007)	Pembuatan Poliol Alkoksi- Hidroksi- Gliserolmonostearat Berbasis Minyak Sawit Sebagai Bahan Baku Foam Poliuretan	Agus Haryono, Evi Triwulandari, Nuri Astrini Widayati	GMS
2.	P00201608791 (20 Dec 2016)	Surfaktan Nonionik Berbasis Asam Oleat Dan Polietilen Glikol Serta Metode Pembuatannya	Yan Irawan, Indri Badria Adilina, Agus Haryono, Muhammad Ghozali, Savitri, Ika Juliana	GMS, GMO, GMOE, SMO, SMS
3.	P00201703488 (31 May 2017)	Proses Pembuatan Poliester Poliol Berbasis Asam Oleat Dan Produk Yang Dihasilkannya	Muhammad Ghozali, Agus Haryono, Achmad Hanafi Setiawan, Yenny Meliana, Evi Triwulandari, Melati Septiyanti, Sri Fahmiati, Athanasia Amanda S., Yan Irawan, Ika Juliana	IPO

Market assessment has been initiated by surfactant business team at RCC LIPI through some activities such as identifying global and national demand, feedstock and supporting raw material availability, and competitors. They have also formulated generic strategy for penetrating the market.

3. Organization aspect

Organization planning for technology development in RCC LIPI is conducted by considering technology transfer activities such as licensing and incubating. Possible routes for technology transfer activities have been also investigated at RCC LIPI, using case of essential oils (Setiawan et al., 2016). The organization development, hence, can be initiated through team building and formalized by management of RCC LIPI. This including the activities for design the organization form, structure and function distribution. When the technology transfer occurs, the formal legal organization arise either by building new organization or using existing organization from partner.

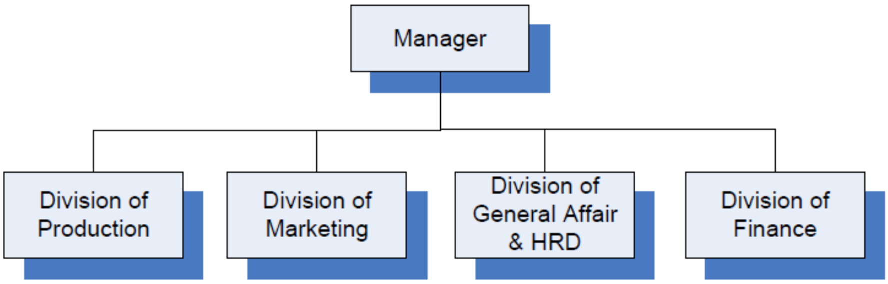

Fig. 5
Example of Organization Structure Design Prepared for Technology Transfer in RCC LIPI (Setiawan, 2013).

One example of organization design is illustrated in Fig. 5. This is a simple design accommodating four main functions of organization, i.e. production, marketing, human resources and finance (Setiawan & Haryono, 2013). This design serves basic form for other researches including surfactants.

4. Partnership aspect

Based on the achievements of research, the partnerships can be formed through collaboration with university and industry. Research at early stages of achievements (i.e.low level of TRL) tends to collaborate with university, while at medium and advances stages can be cooperated with industry. There were some collaboration with industry and university in the past for the development of surfactant researches. However, this collaboration did not last longer for some reasons such as stopped project funding by third parties, retiring principal researchers, changing policies, etc.

Another potential partner for technology transfers is by involving cooperative. This cooperative is an association voluntary initiated by workers of RCC LIPI for the mutual prosperity among its members. Cooperative can provide support in term of incubating like resources such as human resources, equipments, capital, etc.(Haeruddin et al., 2008).

5. Risk aspect

Unlike other aspects, risk assessment has not fully explored in RCC LIPI. Formal risk assessment has been initiated during the team formation for preparing ISO 9001:2015. As risk assessment is one of prequisit for this certification, the team has started to perform assessment, not only in managerial aspect but also in technological developments. However, risk assessment has been performed informally by related researchers on surfactants, particularly in their proposal and report to identify potential failure and counter mechanism.

By considering five aspects altogether, the innovation readiness level of surfactants developed at RCC LIPI for food processing can be depicted in Fig. 6. In this figure, it can be seen that GMS has equal level for all aspects, followed by GMO and IPO.

If we assume that IRL can be described as real number instead of integer (defined as "IRL score"), the similar order results of the overal level for surfactants were also obtained, as illustrated in Fig. 7.

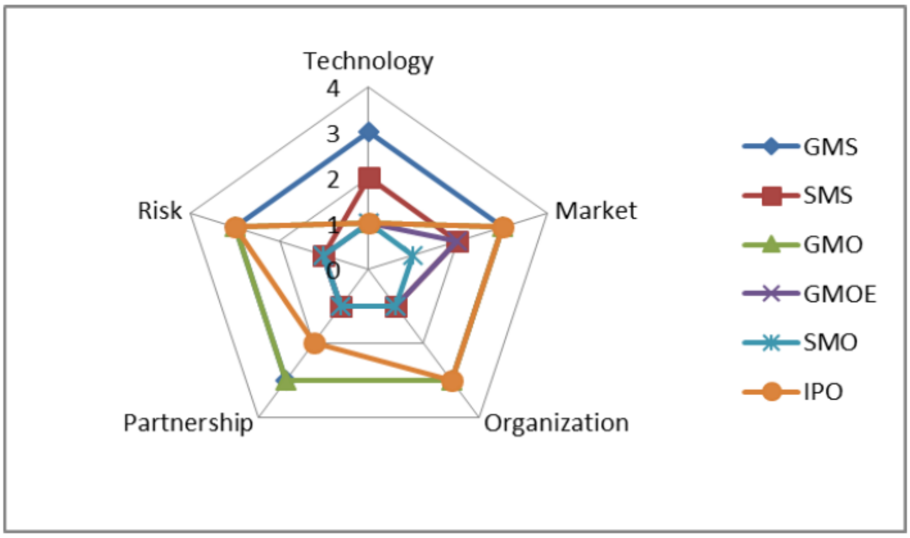

Fig. 6
The Five Aspects of IRL for surfactants developed at RCC LIPI

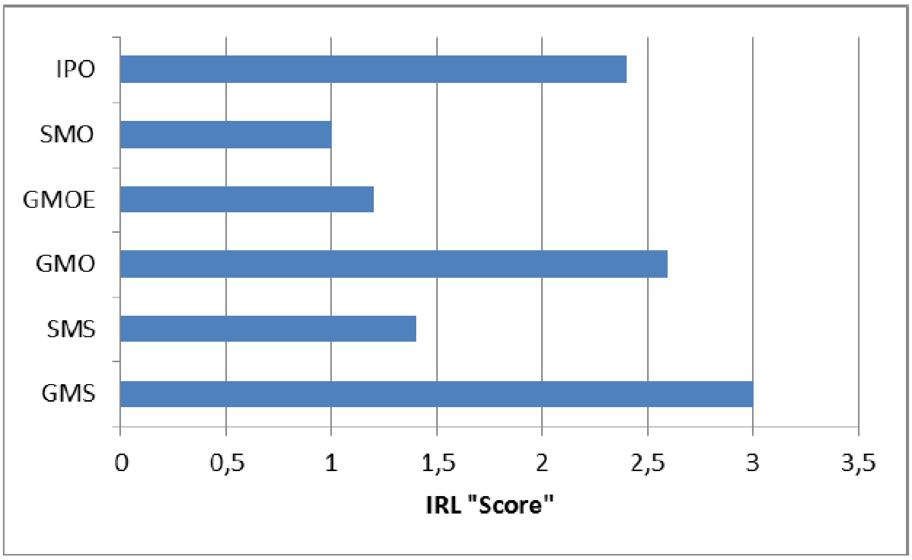

Fig. 7
The IRL Score for surfactants developed at RCC LIPI

These recommended results can be used to formulate strategy and policy for promoting the surfactant research toward commercialization. With limited number of resources such as personnel, facilities and fund, surfactants can be prioritized based on the result from this study. Surfactants with mid to high level of assessment result will be offered to industry for partnership and collaboration, by utilizing the available infrastructure. While low to mid level ones should be encouraged to conducting further research and scaling up by applying relevant funding. Table 4 detailed this potential strategies for improvement further.

Table 4
Improvement Strategy for Commercializing Surfactant Researches

IRL	Surfactants	Potential Improvement Strategies
2-3	GMS, GMO, IPO	Industrial collaboration for mass production, risk assessment, potential differentiation of product application, organizational risk assessment
1-2	SMS, GMOE	Scaling up, system integration, prototype development, partnership contract discussion, supply chain design
0-1	SMO	Scaling up, feasibility analysis, risk analysis, partner finding, market research

CONCLUDING REMARKS

One of the problem faced by the institution of research is lack of quantitative measurement related to technology readiness of research results. As there are lack of common communication language between R & D institutions and industry about the level of preparedness of a research results, it leads to a barrier of technology diffusion.

Innovation Readiness Level (IRL) can be utilized to measure research and development results in universities or research institute as well as industry.

This study has demonstrated the implementation of innovation readiness level framework, as a tool to assess the R&D results. According to IRL assessment of surfactants for food processing in the Research Centre for Chemistry-Indonesian Institute of Sciences, it is obtained that ssurfactants recommended for further development towards commercialization of R&D results, i.e. Glycerol Mono Stearate (GMS), Glycerol Mono Oleat (GMO) and Iso Prophyl Oleat (IPO). Some possible improvements strategies have been also recommended to foster the research toward commercialization.

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