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Some Phase Change Materials Suitable for Cold Storage of Aqua Products

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Abstract
In the food industry, aquatic products can be stored in cold or by freezing. It is economically important for cold chain to maintain important critical temperature values for a longer period of time than usual to prevent microbial, chemical and physical deterioration. Packaging, storage and logistics applications are provided by various materials (styrofoam, polyurethane foam) and non-environmentally friendly petroleum-derived fuels. Along with the fact that materials used in packaging are of high volume and disposable use, and insulation materials that are insufficient during temperature fluctuations lead to product loss and an increase in logistics cost. Latent heat storage, one of thermal energy storage (TES) systems, is a new generation storage system realized with phase change materials (PCM). PCMs that can be applied to different packaging materials can be applied to any external energy source (oil, electricity, solar energy, etc.) for a certain period of time.) it can ensure quality and safety of product by maintaining product storage temperature longer than usual without the need. With PCM, enclosure can provide a lightweight, small in volume and reusable packaging that provides short-term insulation and is an alternative to bulky packaging. This study is a review article that includes PCMs and application methods that may be involved in the cold storage of aquatic products.
Keywords: *Phase change material, Termal energy storage, seafood, food preservation, food packaging material.*

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I. INTRODUCTION

Fish and fish products are considered not only healthiest foods on the planet, but also among the least harmful to environment, and sphere of decisiveness of nutrition strategies in combination with food safety is of vital importance in national, regional agreement. In recent years, fish consumption has accounted for about 17 percent of the total animal protein consumed globally and 7 percent of all proteins. in 2018, the estimated fish consumption per capita is 20.5 kg [1]**.** Fish consumption, average animal protein intake of approximately 3.3 billion people, about Seafood processing arising from the gills and can contain significant amounts of water and microorganisms in intestines. When fish dies, the power defense also stops. As a result of activities of microorganisms found in gills, mouth and skin of fish, as well as enzymes found naturally, there are significant changes in content of fish. Eventually, there are distortions in the taste, smell, vision and texture of the fish.

1.1. Cold storage of aquatic products

Ensuring that fish meat reaches the consumer in a healthy, clean and high quality way requires cooling immediately after production. Be able to maintain quality of fish meat, which is an easily degraded food, for a longer time depends on effectiveness of a widespread and developed cold chain at country level. Therefore, it is necessary to slow down enzymatic and microbial degradation rate by lowering the temperature of the fish to around 0°C immediately after their hunting. Aqua culture; fish, mollusks, etc. ice is one of the indispensable materials in logistics. Heat transfer in fish meat that comes into contact with ice is in the form of direct contact, which ensures the fastest cooling of fish meat. In this method, the temperature of fish is reduced to 0-2° C, where bacterial and enzymatic changes are slowed down. In addition, the melting of ice allows the fish to be cleaned of blood, bacteria and mucous membranes [2]. Fish are usually transported to shore in piles after hunting, unprotected from wind and sun. The absence of insulated sections and fish boxes suitable for storing ice on small and medium-sized fishing boats is important for fishing due to cost of insulation for this purpose, as well as the several-hour period that will pass between fishing and decanting and icing the fish [3]. Ringlets that are iced immediately after hunting (Clupea harengus harengus L.) it could remain intact for 7-12 days, while the fish that was iced after waiting 4-6 hours in open could only be stored for 4-7 days. Similar results were obtained from sardines (Sardinella pilchardus Sardina), mackerel (Scomber scombrus L.) and anchovies (Engraulis encrasicholus L.) has also been detected in fish [4; 5]. There have been many studies on the effect of packaging process on fish and shellfish microflora. The shelf life of cultured trout (Salmo gairdneri) is doubled when 80% CO_2 and 20% N_2 are stored in the atmosphere. Trout deteriorates within 12 days when stored unpacked. The modified atmosphere was determined by the sensory panel after cooking trout, which is acceptable for packaged fresh trout after 25 days of storage at 1.7 ºC. The 2.3% potassium sorbate treatment of trout before modified atmosphere packaging did not increase its shelf life [6]**.** In general, aquaculture, fresh water, sea water, brackish water and salt water in these environments using fin fish, crustaceans, mollusks, aquatic plants, mostly algae also is the cultivation of aquatic animals for inclusion. The steps taken in agricultural production in the food supply chain are; post-harvest processing and storage; processing and packaging; distribution and consumption. Increase in the world's population has led to an urgent increase in food supply, and it has become important to reduce loss of food after harvesting. January July 2015 to January 2016, a survey of 150 fishermen, 90 fish handlers and 90 fish sellers was conducted to assess post-harvest fish losses at Albert Bosomtwi-Sam fishing port in Sekondi in the Western Region of Ghana to identify Sardinella maderensis (Madeiran sardinella) and loss of 92 tons of aurita (sardine) species of fish from 2010 to 2016 and identified types of losses were calculated as quality losses (50%), physical losses (32%) and sunday losses (12%). In addition, leading causes of fish losses after harvesting are; insufficient ice (10%), long stay in the port (33%), poor processing technique (30%) and gear-related injuries (28%) [7].

The world production of cultural fishery set an all-time record with 114.5 million tons per live weight in 2018. The total production is:
• 82.1 million tons of aquatic animals
• 32.4 million tons of seaweed
• 26,000 tons of ornamental seashells and pearls
In 2018, domestic produced in natural water sources such as rivers and lakes and fish farms in inland aquaculture, animal production 51,3 million tons of farmed fish produced per cent of the world's water, which has 62,5% in the production of aquatic animals from farm type culture fisheries worldwide, in the last twenty years, approximately 89% of Asia with a share of the hegemony. The main producing countries over the past two decades include China, Dec, Indonesia, Vietnam, Bangladesh, Egypt, Norway and Chile. in 2018, about 88% of the total fish production of 179 million tons was used for direct human consumption. in 2018, live, fresh or chilled fish accounted for the largest share (44%) of fish used directly for human consumption. A large part of 35% of the production of fisheries and cultural fisheries is lost or wasted [8].

1.2 Phase change materials and latent heat storage

Energy can be stored in different ways, such as mechanical, electrical, chemical and thermal energy storage. Functional food packaging materials, as well as petroleum, electrical, etc. quality and safe food preservation is possible by using as few energy sources as possible. Energy storage is a useful tool for improving energy efficiency and energy saving. There are three ways to store energy: chemical energy (reversible reactions), felt heat and latent heat. In thermal energy storage, latent heat is the amount of heat that changes its physical structure and is constant when the material is in a solid, liquid, and gaseous state. Among these ways, latent heat storage is the most attractive due to the fact that very large amounts of energy are stored and decoupled per unit weight of a phase change material (PCM) at an almost constant temperature [9] **.**Compared to other heat storage methods, the required storage volume is small, but the heat storage capacity is high. Food packaging containing PCM, on the other hand, can significantly reduce or prevent temperature fluctuations that may occur in food [**10].** PCMs that can store heat energy at low temperatures are the materials needed for cold storage. It may be possible to evaluate solid-solid, solid-liquid, liquid-gas phase change PCMs as packaging materials by microcapsulating them.

1.3 PCM application methods

Considering the applications in this field, especially in solid-liquid phase transitions, PCM should be encapsulated. Otherwise, the liquid phase may leak out [11].The main purpose of PCM microcapsulation is that the substance is trapped in the capsule and the phase change occurs in the capsule. The microcapsule consists of a polymeric wall and the liquid substance covered by this wall. The capsule wall is an inert substance against PCM inside [12]. PCMs in cold storage; It stores the storage heat as latent heat with phase change and maintains the ambient temperature for a long time by giving back this latent heat stored in temperature increases and decreases and at this time, it also provides insulation in a way by preventing the heat from reaching the food. In the solid-liquid phase change, heat energy stored by the PCM in the solid state is released during the transition to liquid state [13]**.** The energy stored in PCM is able to maintain deckhouse heat for 4 to 8 hours depending on the thermal load without an electric power supply using a 5 mm thick plate [14]. Recently PCM for cold storage as C12-C14 (dodekane-tetradekan) and C13-C15 (tridekane-pentadekane) n-alkanes were prepared and eutectic mixtures of latent heat storage temperature ranges from (-12)-(4) and ^{0} C (-5)-(10) ^{0} C is manufactured [15].

Another cold preservation study is the PS/ n-tetradecane microcapsule study, and a phase change between (-3)-(4) °C was observed [16]. Again, research on n-tridecane as PCM has been limited to the detection of latent heat melting temperature and enthalpy [17]. Enthalpies of some other PCMs that can be used for cold storage purposes are shown in Table 1.it is also given.

Table 1. Some PCMs suitable for cold storage of aquatic products and their thermal properties

Name	Type	Melting temperature(°C)	Heat of fusion (kJ/kg)	Refs.
MPCM (-30)	Parafin	-30	140–150	[18]
SN 29	Salt solution	-29	233	[19]
SN 26	Salt solution	-26	168	[19]
-	Salt hydrate	-23	230	[20]
TH	Salt hydrate	-21	222	[19]
SN 21	Salt solution	-21	240	[19]
STL 21	Salt solution	- 21	240	[19]
ClimSel C-18	Salt solution	-18	306	[21]
SN 18	Salt solution	-18	268	[19]
TH 16	Salt solution	-16	289	[19]
AN 15	Salt solution	-15	311	[19]
AN 12	Salt solution	-12	306	[19]
STLN 10	Salt solution	-11	271	[19]
AN 10	Salt solution	-11	310	[19]
TH 10	Salt solution	-10	283	[19]
MPCM (-10)	Paraffin	-9.5	150–160	[18]
STL 6	Salt solution	-6	284	[19]
AN 06	Salt solution	-6	284	[19]
RT-4	Paraffin	-4	179	[22]
TH 4	Salt solution	-4	386	[19]
SLT 3	Salt solution	-3	328	[19]
AN 03	Salt solution	-3	328	[19]
-	Salt solution	0	335	[20]
RT 3	Paraffin	4	198	[22]
RT 4	Paraffin	4	182	[22]
Al $(NO_3)_3$ (30.5 wt.%) + H_2O Eutectic water	Salt solution	- 30.6	131	[23]
Diethylene glycol	Eutectic	-10	247	[23]
Dodecane Organic	Paraffin	-9.6	216	[24]
Triethylene glycol Organic	Paraffin	-7	247	[23]
Tetradecane + Octadecane Organic Eutectic	Paraffin	-4.02	227.52	[24]
H_2O + polyacrylamide	Flocculant	0	295	[23]
91.67% tetradecane + 8.33% hexadecane Eutectic organic	Paraffin	1.7	156.2	[24]
Tetradecane + docosane Eutectic organic	Paraffin	1.5–5.6	234.33	[24]
Tetradecane + Geneicosane Eutectic Organic	Paraffin	3.54–5.56	200.28	[24]
K_2HPO_4 $6H_2O$	Salt hydrates	4	109	[25]
Na_2SO_4 (31 wt. %)	Inorganic eutectic compounds	4	234	[26]
Tetradecane + Docosane	Paraffin	1.5-5.6	234.33	[19]

II.RESULTS AND DISCLOSURES

The main application of phase change material is food storage containers. Organic and inorganic PCMs have been tried by many researchers to reveal the maximum thermal efficiency available [27]. PCMs that can store heat energy at low temperatures are the materials needed for cold storage. FDMS have a single use in packaging aquaculture (Styrofoam, etc.) the ability to produce reusable packaging materials that can be sterilized instead of materials and provide zero waste, the ability to store warehouse heat and maintain it for a certain period of time in temperature drops and rises, hybrid systems (solar energy, wind energy, etc.) dec can be considered among the advantages that it can provide that it can provide 100% green energy when used with.

III.CONCLUSION

PCM containing packaging materials that can be applied to foodstuffs that can be stored at low temperatures as well as in aquaculture storage can reduce the cost of food by saving on petroleum-derived fuel and electrical energy, as well as disposable styrofoam, etc. it can also reduce environmental pollution caused by packaging. It is believed that the widespread use of food packaging containing PCM can reduce greenhouse gas emissions by reducing the cost of food logistics worldwide, as well as enable consumers to eat healthy by providing cheaper food consumption.

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