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# GLYCEROPHOSPHOLIPID ANALYSIS OF EASTERN RED BAT (*Lasiurus borealis*) HAIR BY ELECTROSPRAY IONIZATION TANDEM MASS SPECTROMET

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## Abstract

Pilosebaceous units found in the mammalian integument are composed of a hair follicle, the proximal portion of the hair shaft, a sebaceous gland, and the erector pili muscle. Pilosebaceous units release protective oils, or sebum, by holocrine secretion onto skin and hair through rupturing of sebocytes. Sebum is largely composed of polar and neutral lipids including glycerolipids, free fatty acids, sterols, wax esters, sterol esters, and squalene. In addition to these lipid classes, there is a small proportion of ionic/anionic glycerophospholipids (GPs). Composition of GPs on hair is rarely addressed despite their broad biological activities as signaling molecules and membrane stability. Furthermore, knowledge on GP composition in bats is lacking. Bat GP composition is important to document due to GP roles ranging from decreasing drag during migration to interaction with the integumentary microbiome. In this study, we analyzed GP molecular composition with liquid chromatography electrospray ionization tandem mass spectrometry and compared GP content to previous literature. A total of 152 GPs were detected. Broad GP classes identified include lysophosphatidylcholine, phosphatidylcholine (PC), lysophosphatidylethanolamine, phosphatidylethanolamine, phosphatidylinositol, phosphatidylserine, phosphatidic acid, and phosphatidylglycerol, with PC being the most abundant class. The acyl components were consistent with fatty acid methyl esters and triacylglyceride moieties found in Eastern red bat sebum. GP proportions of the hair surface were different from a previous study on bat lung surfactants. This study determined the broad class and molecular species of bat sebum GPs that may be used in future ecological studies in vespertilionid bats.

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**Keywords**

Glycerophospholipid; Eastern red bat; Electrospray Ionization MS/MS; Sebaceous Secretions; Hair Phospholipids

## INTRODUCTION

The mammalian integument contains pilosebaceous units which are composed of a hair follicle, the proximal portion of the hair shaft, a sebaceous gland, and the erector pili muscle (Spearman, 1963). Pilosebaceous units release protective oils onto the skin by holocrine (i.e., rupturing of individual sebocytes) and apocrine secretions (Smith and Thiboutot, 2008; Maier et al. 2011; Sugawara et al. 2012). Surface lipid (sebum) is largely composed of a complex mixture of polar and neutral lipids including glycerolipids (i.e. triacylglycerides [TAGs], diacylglycerides [DAGs], and monoacylglycerides [MAGs]), free fatty acids (FFAs), sterols, wax esters (WEs), sterol esters (SEs), and squalene (Drake et al. 2008). Sebum contributes to the innate immune system (Georgel et al. 2005; Napolitano and Juarez, 1997), pheromone release (Kligman, 1963; Brooke and Decker, 1996; Nassar et al. 2008; Muñoz-Romo et al. 2012), water repellency (Porter, 2001; Eiseinger et al. 2011), hydration and organization of the stratum corneum (Pilgram et al. 2001; Smith and Thiboutot, 2008), compound adsorption (Tsai et al. 2012), bat communication (Safi and Kerth, 2003), and ultraviolet protection (Picardo, et al. 2009; Camera et al. 2010) among others (Haffner, 2000). Sebaceous secretions may play a role in the pathogenesis of *Psuedogymnoascus destructans*, a fungus that causes cutaneous infections in bats (white nose syndrome) and mass mortalities of North American cave species (Blehert et al. 2009; Gargas et al. 2009; Lorch et al. 2011; Minnis and Lindner 2013). A minor lipid contribution from epidermal cells found in surface lipid that is rarely emphasized is glycerophospholipids (GPs), possibly due to its obscure function (Eckstein, 1927).

GPs are an abundant class of lipid in mammals and serve diverse functions (Hanahan, 1997). Common GPs are divided into eight main classes (lysophosphatidylcholine [Lyso PC], phosphatidylcholine [PC], lysophosphatidylethanolamine [Lyso PE], phosphatidylethanolamine [PE], phosphatidylinositol [PI], phosphatidylserine [PS], phosphatidic acid [PA], and phosphatidylglycerol [PG]) according to the polar head group (Fig. 1); however, other smaller classes are grouped in this broad class (Fahy et al. 2005, 2009). A majority of GPs found in biological organisms are PC, but PE and PS may be found in high abundance depending on the organism and tissue (de Kroon, 2007). GPs may play a role in host/pathogen interactions. Host PC may be utilized for microbial choline requirements and subsequent pathogenesis of these organisms (Comerci et al. 2006; Aktas et al. 2010). GPs are important sources of inositol for fungal pathogens (Reynolds 2009). *Stachybotrys chartarum* has been shown to alter host GP content in pulmonary surfactants during infection (Hastings et al. 2005). GPs are components of cellular membranes (Hanahan 1997) and may function in cellular signaling (Nishizuka 1992,) or as pulmonary surfactants (Pison et al.1994) and antimicrobial agents (Arouri and Mouritsen 2013). GPs have also been hypothesized to function in spermatozoa survival in bats (reviewed in Racey, 1979). Given the ubiquity of GPs coupled with their array of biological functions the

composition of these compounds on the surface of bat integument is important to quantify and catalog.

While reports have discussed in detail bat sebaceous glands ultrastructure (Cortese and Nicholl, 1979; Nassar et al. 2008), the chemical composition of bat sebum (Pannkuk, et al. 2012; 2013a), and bat stratum corneum lipids (Muñoz-Garcia et al. 2012), surprisingly little on GP composition of bat integumentary lipids is known. Furthermore, few studies have reported GP content of the hair surface. For this reason we excised Eastern red bat (*Lasiurus borealis*) hair tissue, isolated the lipid fraction, and submitted lipid for analysis at the Kansas Lipidomics Research Center (KLRC) for electrospray ionization tandem mass spectrometry (ESI-MS/MS) to determine GP class and acyl constituents. Finally, we compared the GP content of *L. borealis* to previously published literature.

## METHODS AND MATERIALS

Hair of *L. borealis* (1.0 g) was removed with scissors and lipid was immediately isolated with chloroform:methanol (C:M) as previously described (Pannkuk et al. 2012; 2013b) (Arkansas State University's Institutional Biosafety Committee approval # 135349-1). This relatively non-destructive method minimized integral hair lipids rather than sebaceous secretions present in the sample. Eastern red bats were collected from the Ozark St. Francis National Forest, AR during July 2010. Bats were collected within four weeks and no juveniles, pregnant females, post-lactating females, or migrating individuals were sampled. Hair from male and female individuals were removed and combined. Hair was combined between sexes due to the large amount of hair (~10–15 individuals) required to obtain 1.0 g. Analysis of surface lipid fatty acid methyl esters (FAMEs) between sexes show no statistical difference while juveniles have higher proportions of unsaturated FAMEs (Pannkuk, data not shown). All storage solvents contained 0.05% butylated hydroxytoluene (Law et al. 1995). Five independent samples (1.0 g each) in total were collected, dried under $N_2$, stored on dry ice, and overnight shipped to KLRC. All solvents were of HPLC grade (Fisher Scientific, U.S.A.). GP analysis was performed by ESI-MS/MS by determining the *m/z* of the intact ion and the head group fragment *m/z* (see Wanjie et al. 2005; Lattif et al. 2011). Percentages are reported as the normalized signal/tissue mass as compared to 1 nmol internal standard (reference Lattif et al. 2011 for standards used). Percentages reported within class are as percent of total GP content. Broad classes of GPs were compared by a Kruskal-Wallis test (SAS 9.2, Cary, NC, U.S.A.).

## RESULTS

A total of 151 GP compounds were identified (Table 1). GP compounds were identified as intact ion *m/z* and assigned to a broad GP class based on head group fragment *m/z*. Therefore, saturation and individual acyl C number were only determined for Lyso GPs. Significantly higher amounts of PC was detected on bat hair surface ($\chi^2$=24.97, $P$=<0.001) than other classes (Fig. 2). The majority of Lyso PC detected was 16:0, 18:1, and 18:0 (2.3, 1.2, and 1.1% of total GPs detected respectively) (Fig. 3). Lower levels of 18:2 and 17:0 were detected (0.4 and 0.1% respectively). The majority of Lyso PE was 18:1 and 16:0 (0.4 and 0.1% respectively) (Fig. 3). The predominant molecular structure of PI, PG, and PC was

34:1 (5.0, 0.9, and 20.6% respectively), with 32:0 being the second most abundant in PC (10.6%), 36:2 in PI (3.7%), and 32:0 in PG (0.3%) (Fig. 4). In PE and PS 36:1 (1.5 and 1.4% respectively) was the predominant compound with high amounts of 36:2 (1.0%) and 34:1 (0.7%) found in PE (Fig. 5). The dominant form of PA was 32:0 (0.5%) with lower amounts of 36:4 (0.2%) and 36:1(0.3%) (Fig. 6). From the literature and previous research, the predominant acyl moieties for the major GPs are likely as follows: 32:0 (16:0/16:0), 34:1 (16:0/18:1), 36:2 (18:1/18:1), 36:1 (18:1/18:0), and 36:4 (18:2/18:2 or 18:3/18:1).

## DISCUSSION

In this study, we determined GP content by high throughput liquid chromatography ESI-MS/MS. With over 100 phospholipids known from mammals (Yamashita et al. 2014), cataloging GPs present on fur, combined with sebum composition from other body regions (Pannkuk et al. 2012, 2013a, 2013b), is a critical first step before making and testing predictions about the role of these lipid molecules in the ecology of free-living animals. *L. borealis* is a particularly interesting species for investigation due to a number of ecological and life history factors.

Glandular lipid secretions have anti-microbial properties in birds, effective against feather-degrading bacteria (Shawkey et al. 2003) and overall bacterial load (Czirjak et al. 2013). The role of similar keratinolytic bacteria affecting bacterial load in mammalian fur as received little attention (see Yamamura et al. 2002) but GPs coupled with other lipid molecules could have an important role in defining host microbiota. Of particular relevance to *L. borealis* is the possibility that keratin-degrading bacteria may affect carotenoid-based coloration (Shawkey et al. 2009). The fur of *L. borealis* is sexually dimorphic, a highly unusual trait among bats, with males tending to higher reflectance in the red spectrum (i.e. higher intensity red coloration) than females (Shump and Shump 1982). The role of sexual dimorphism in *L. borealis* is unknown, but GPs or other surface lipids may mitigate the potential negative effects of keratin-degrading bacteria. Given the amount of sample required for analysis, it was not possible to separate males and females in our study. Future work should test for sex effects in the composition of GPs on bat fur, especially the sexually dimorphic *L. borealis*.

The composition of fur lipids may also be related to roosting ecology. *L. borealis* is a foliage roosting bat (Kunz and Lumsden 2003), and is therefore more exposed in the roost than cavity roosting species. The fur of *L. borealis* (and other foliage roosting Lasiurine bats) is denser and more extensive than most other bat species (Shump and Shump 1980), further emphasizing the importance of understanding the composition and role of fur surface lipids. The water repellent properties of sebum lipids could be particularly important in species such as *L. borealis* that may be more exposed to rain when roosting. In the winter months, *L. borealis* roost in leaf litter when temperatures approach freezing and can remain for several days/weeks until temperatures increase (Mormann and Robbins 2010). While buried in leaf litter, the antimicrobial properties of GPs (and other components of sebum) could be particularly important to hibernating *L. borealis*.

Bat fur surface lipids could also play an important role in flight aerodynamics. Bat fur affects drag experienced in flight (Hassanloo et al. 1995). Although untested, it has been suggested that preen wax on the feathers of birds may play a role in reducing drag during flight (Thomas et al. 2010). This speculation is supported by that fact that there was more preen wax on head feathers (the leading part of the body during flight) than wing or tail feathers (Thomas et al. 2010). Similarly, there is an increased sebum production on the head of vespertilionid bats (Haffner 2000). As aerial insectivores, *L. borealis* typically spend approximately 2 h in foraging flight each night (Hickey and Fenton 1990) and may spend much longer during pregnancy and lactation (lactating *L. cinereus* spend up to 6 h in foraging flight; Barclay 1989). Furthermore, *L. borealis* is a long-distance migrant (Cryan 2003) and fur surface drag reducing properties of lipids may reduce energetic demands imposed by migration. It would be interesting to test for seasonal changes in the composition of fur surface lipids, as observed for muscle membrane GP composition of migrating *L. cinereus* (McGuire et al. 2013). Alternatively, it is possible that seasonal variation may be related to variation in diet, as suggested for variation in the adipose fatty acid profile of migrating and non-migrating *L. cinereus* (Price et al. in press).

In terms of GP content in *L. borealis* compared to other studies, GP content is primarily PC, with PI being the second most abundant. Previously reported values state PC is slightly higher than PE in human *in vitro* grown sebaceous glands (Downie and Kealey, 1998) and the dermal portion (with sebaceous glands) of hair transplant recipients (Stewart et al. 1978). GPs are not usually detected in sebum sampled *in vivo* in most organisms (Emara and El-Mokaddem 1979), which may be due to GPs being converted to wax esters or FFAs by lipases or due to the use of analytical techniques with low sensitivity (e.g., thin-layer chromatography) (Downing et al. 1974; Colton and Downing 1985). Another plausible explanation is low occurrence of lipase activity or oxidation present in bat pelage, as the lipid content of bat hair is found to resemble the sebocyte lipid rather than the secreted sebaceous lipid of wings (Pannkuk et al. 2012, 2013a). On human hair surface, PS was found to be the dominant GP followed by PE, PC, and Lyso PC respectively (Singh and Gershbein, 1968). GPs have been found to be major constituents of secreted fish mucus with PE being the major class (Lewis 1970). Additionally, high proportions of GPs have been found in the sebum of cattle (9.6%, McMaster et al. 1985)

Molecular identification of GP classes in bats is lacking. Levels of total GP were quantified but not identified to molecular level in the pulmonary surfactant of the lesser long-eared bat (*Nyctophilus geoffroyi*) (Slocombe et al. 2000). Total GP and fatty acid methyl ester (FAME) content was determined for the sperm of five *Pteropus* species (i.e. *P. vampyrus*, *P. giganteus*, *P. poliocephalus P. hypomelanus*, and *P. rodricensis*) (Melville et al. 2012). GP FAME was determined to vary by sex and migratory status in hoary bat (*L. cinereus*) muscle tissue (McGuire et al. 2013). GPs (124 molecules) were identified but not reported for the fishing bat (*Noctilio leporinus*) subaxial secretions (Brooke and Decker, 1996). GPs were quantified in lung surfactant of Gould's wattled bat (*Chalinolobus gouldii*) (Lang et al. 2005). The major PC found in Gould's wattled bat lung surfactant was 32:0 followed by 33:2 and 34:1 (Lang et al. 2005). Our present study is in contrast to Lang et al. (2005) with 34:1 being dominant followed by 32:0 for PC; however, this result is not surprising

considering the different functions of lung surfactant to sebaceous lipid. Our results for PG are similar as 34:1 is the dominant species followed by 32:0, but a lower proportion of 36:2 was detected. Lang et al. (2005) reported 32:0, 34:2, 34:1, 36:2, 36:4, and 38:4 of total PI being approximately equal but we found high proportions of 34:1, 36:2, and 36:1. These contrasts show that GP levels are not comparable among tissues and/or species.

The abundance of 34:1, 32:0, and 36:1 GPs suggest that 18:0, 18:1, and 16:0 are the dominant bat GP moieties, which have also been reported for the TAGs, FFAs, and MAGs of *L. borealis* integument and the dominant FAME of total lipid extract of bat sebum (Pannkuk et al. 2012, in prep). The FFAs of *L. borealis* were found to be mostly 16:0 (~33%) with equal amounts of 18:0 and 18:1 (~22 and 24% respectively). Acyl moieties of *L. borealis* TAGs determined by ESI-MS/MS indicate 18:1 and 16:0 comprise ~48 and ~37% of the acyl content respectively. Analysis of MAGs by GC/MS indicates 18:0 and 16:0 comprise 75 and 22% respectively. FAME analysis of *L. borealis* sebum indicates a majority 16:0 (37%) with lower amounts of 18:0 (34%) and 18:1 (11%) acyls comprise the saponifiable fraction of total lipid extract (Pannkuk, results not shown). To our knowledge, this study is the first analysis of the molecular identification of GPs found on the surface of bat hair and the only quantitative report on bat GPs by ESI-MS/MS other than Lang et al. (2005). Bat GPs are uniquely different from that found on human hair in that bat PC is the dominant GP present on the hair surface, whereas from human hair PS was the dominant GP. Proportions and types of GPs are likely different among tissue types and possibly species. Secreted bat hair lipid proportions resembles intracellular membrane lipid more than wing sebum (Pannkuk et al. 2012, 2013a). Similarities between hair surface lipid and wing keratinocyte lipid could be explained by lower oxidation or lipase activity in bat pelage or possibly a greater contribution from keratinocytes on the hair shaft secretions. While GPs are rarely reported as sebum constituents these compounds have been found in cattle sebum. Acyl moieties of *L. borealis* GPs are consistent with other lipid classes found on the hair surface. Further studies should determine functional significance of the compounds on the pelage in sexual signaling, water proofing, microbial attachment, aerodynamics, or other functions.

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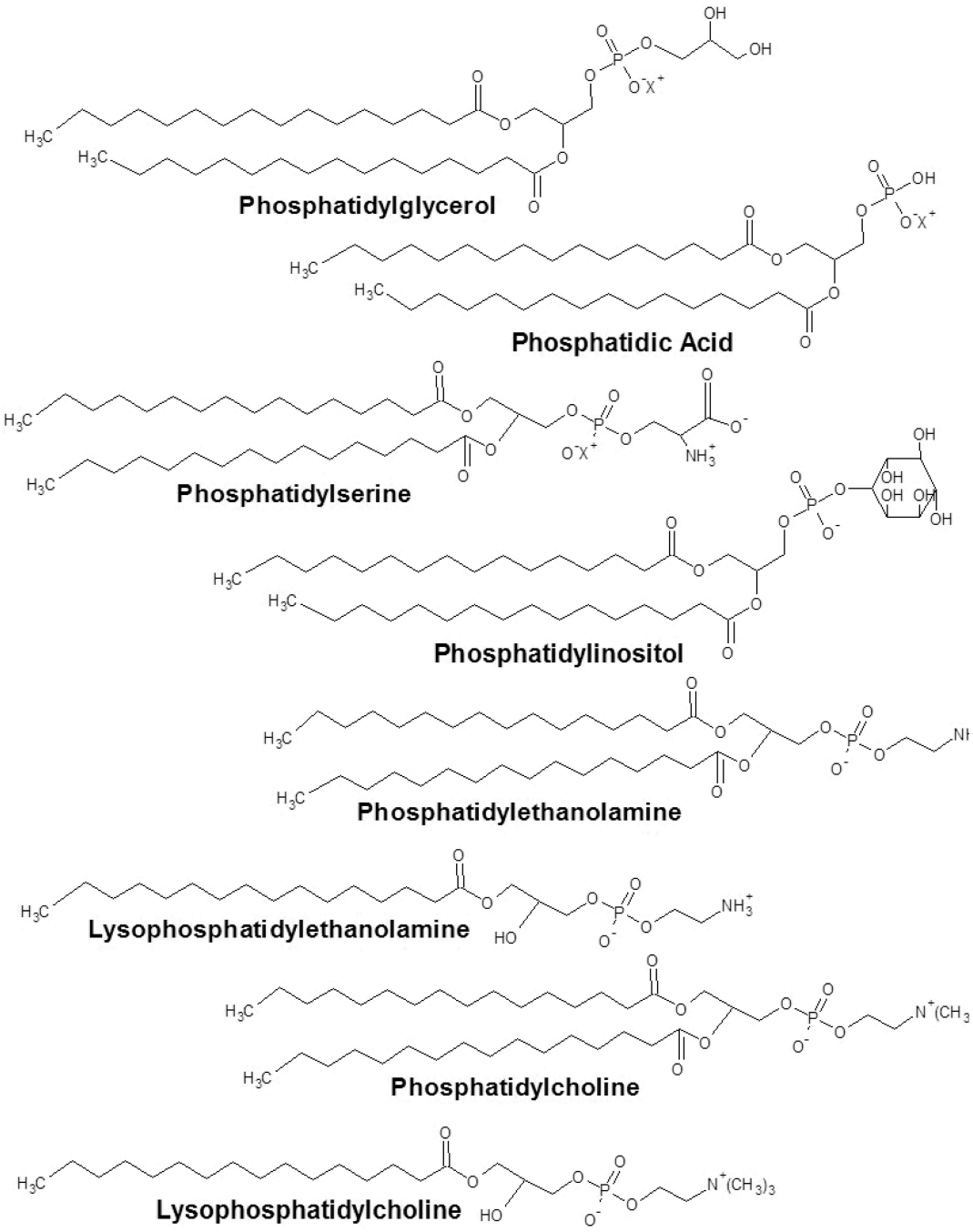


**Fig. 1.**
Structures of the major classes of glycerophospholipids.

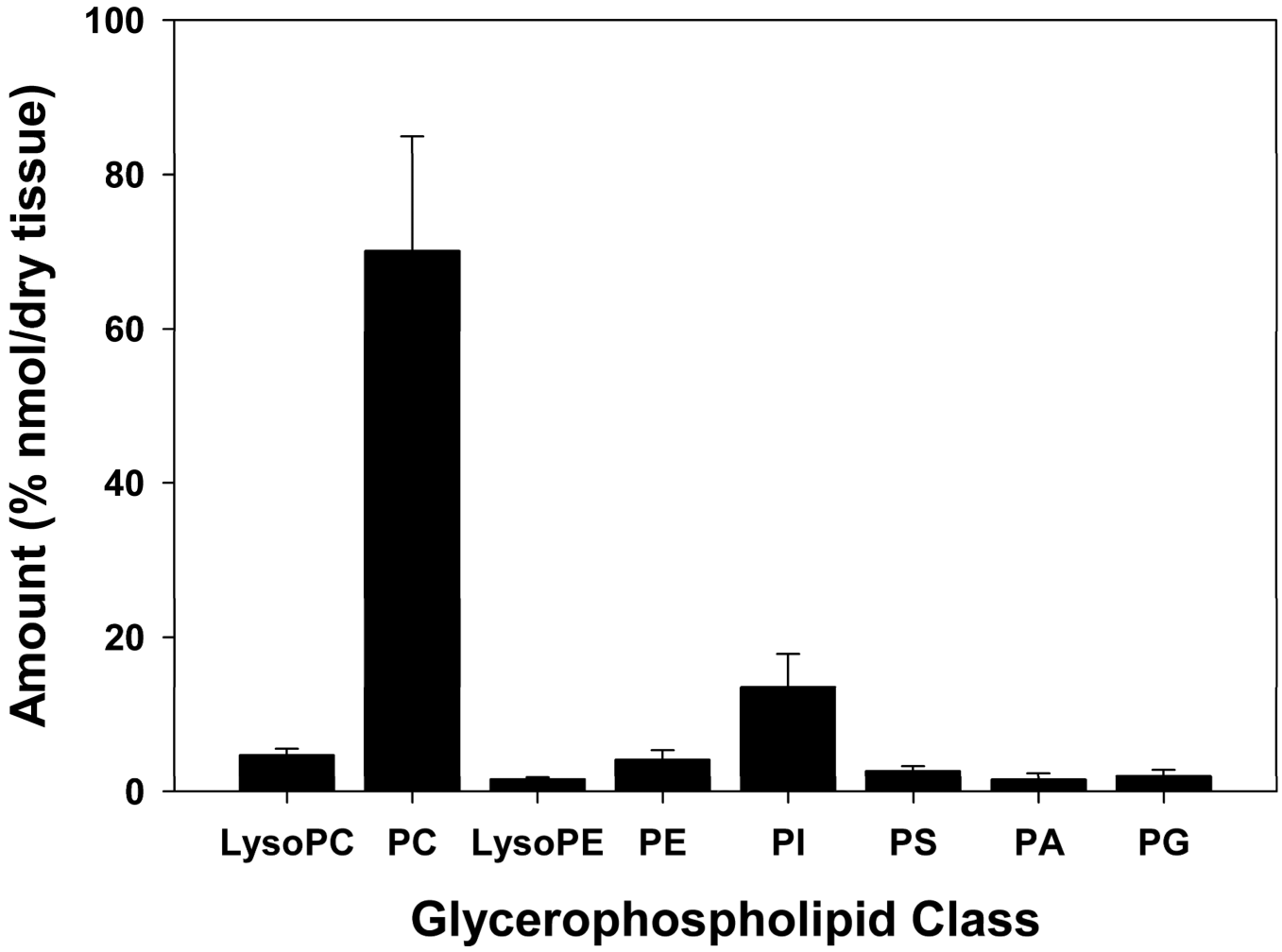


**Fig. 2.**
Percentage of glycerophospholipid class in *Lasiurus borealis* hair (Amounts nmol/dry tissue weight, Means±S.E.).

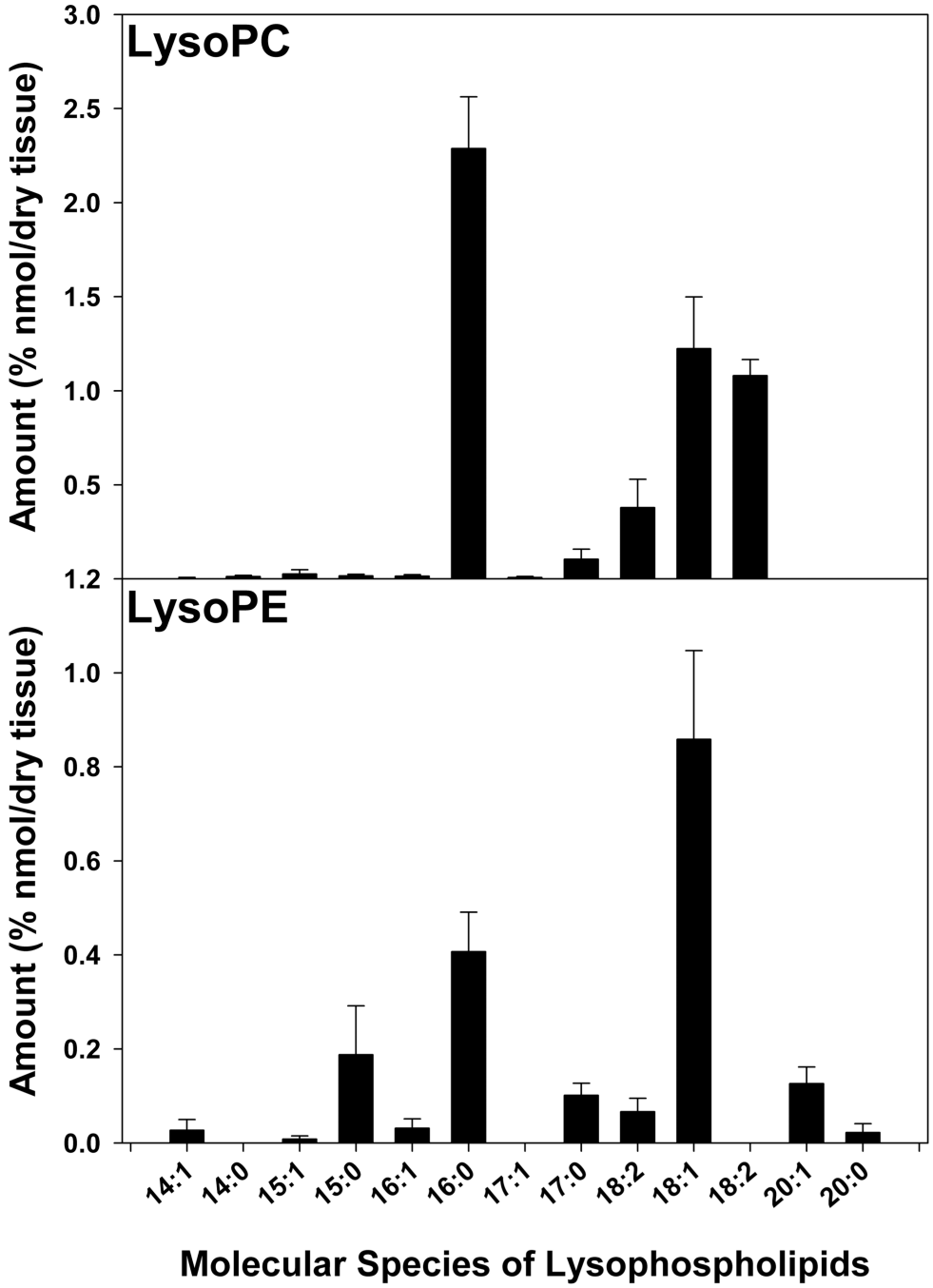


**Fig. 3.**

Percentage of lysophosphotidylcholine and lysophosphatidylethanolamine in *Lasiurus borealis* hair, (Amounts nmol/dry tissue weight, Means±S.E.).

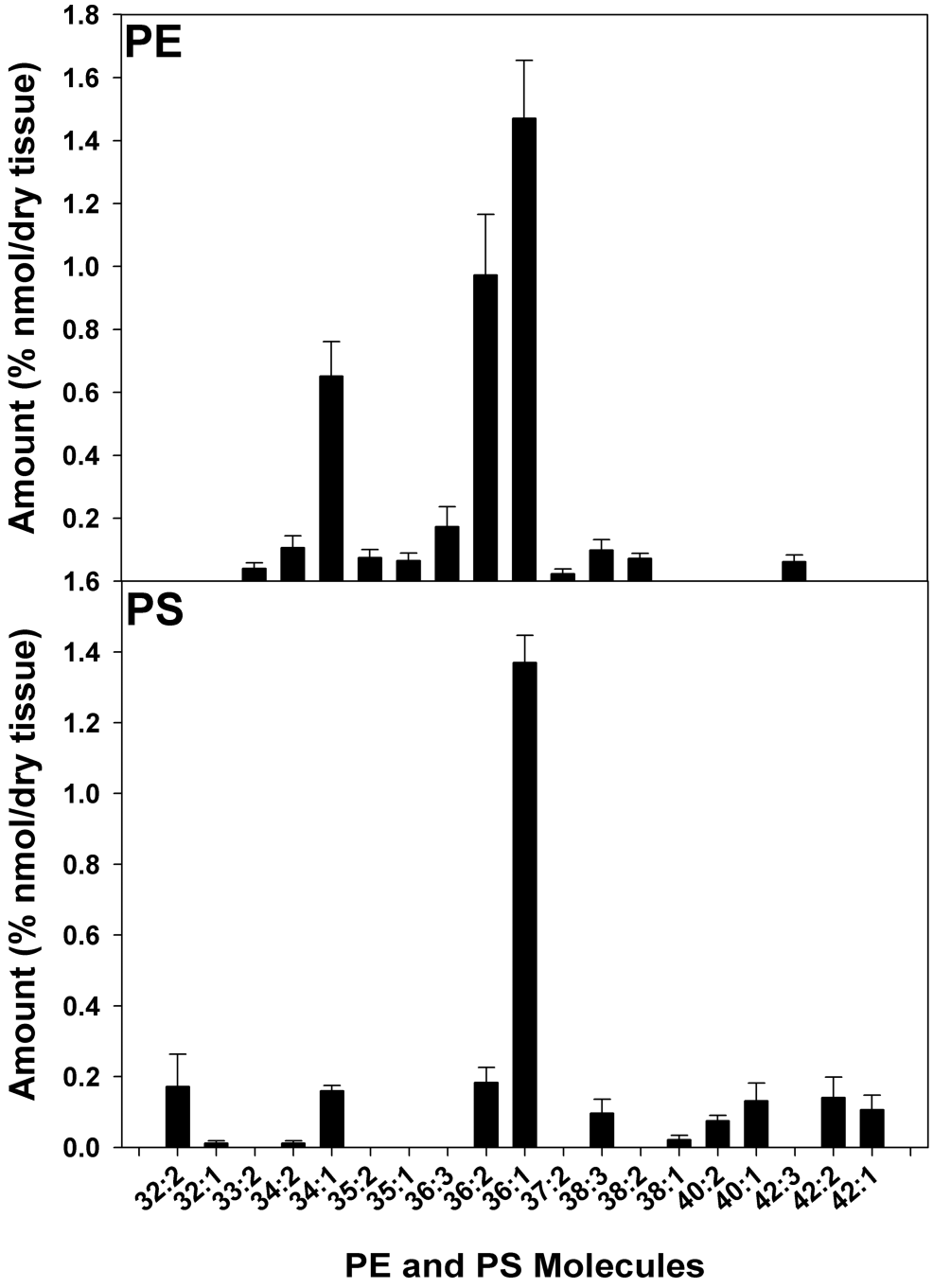


**Fig. 4.**

Percentage of phosphatidylethanolamine and phosphatidylserine in *Lasiurus borealis* hair, (Amounts nmol/dry tissue weight, Means±S.E.).

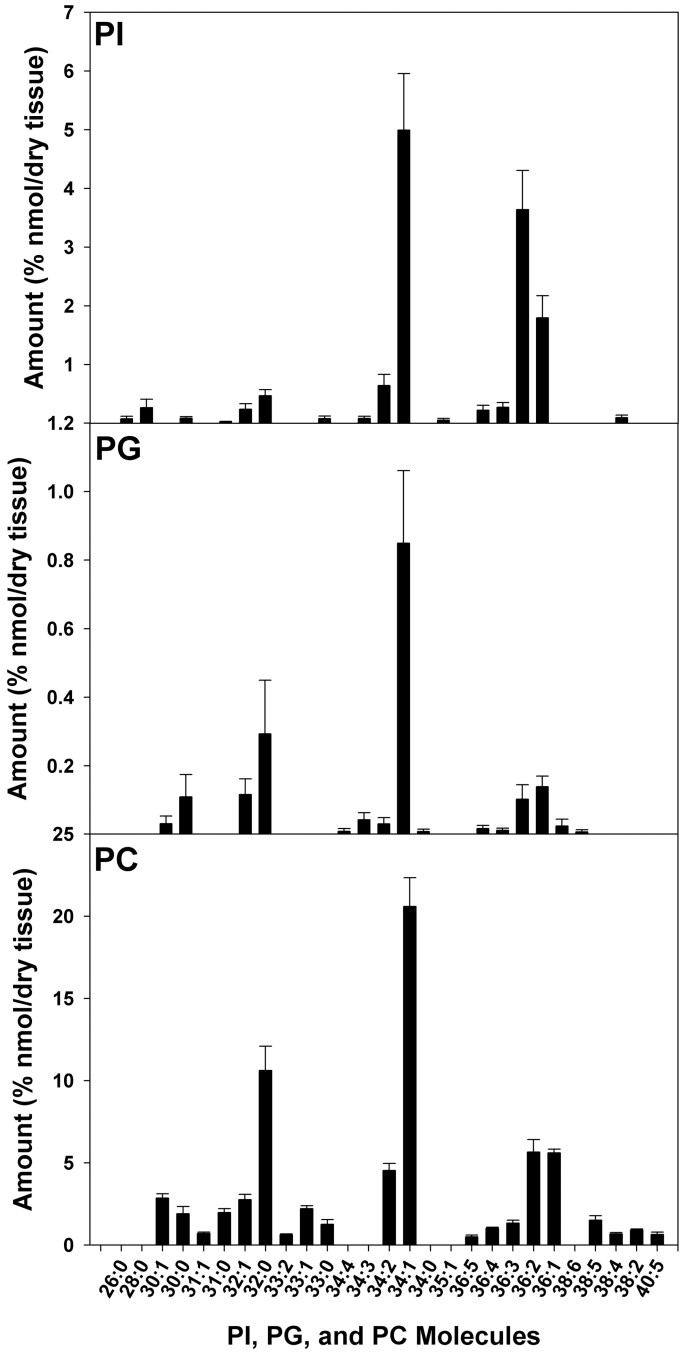


**Fig. 5.**

Percentage of phosphatidylinositol, phosphatidylglycerol, and phosphatidylcholine in *Lasiurus borealis* hair, (Amounts nmol/dry tissue weight, Means±S.E.).

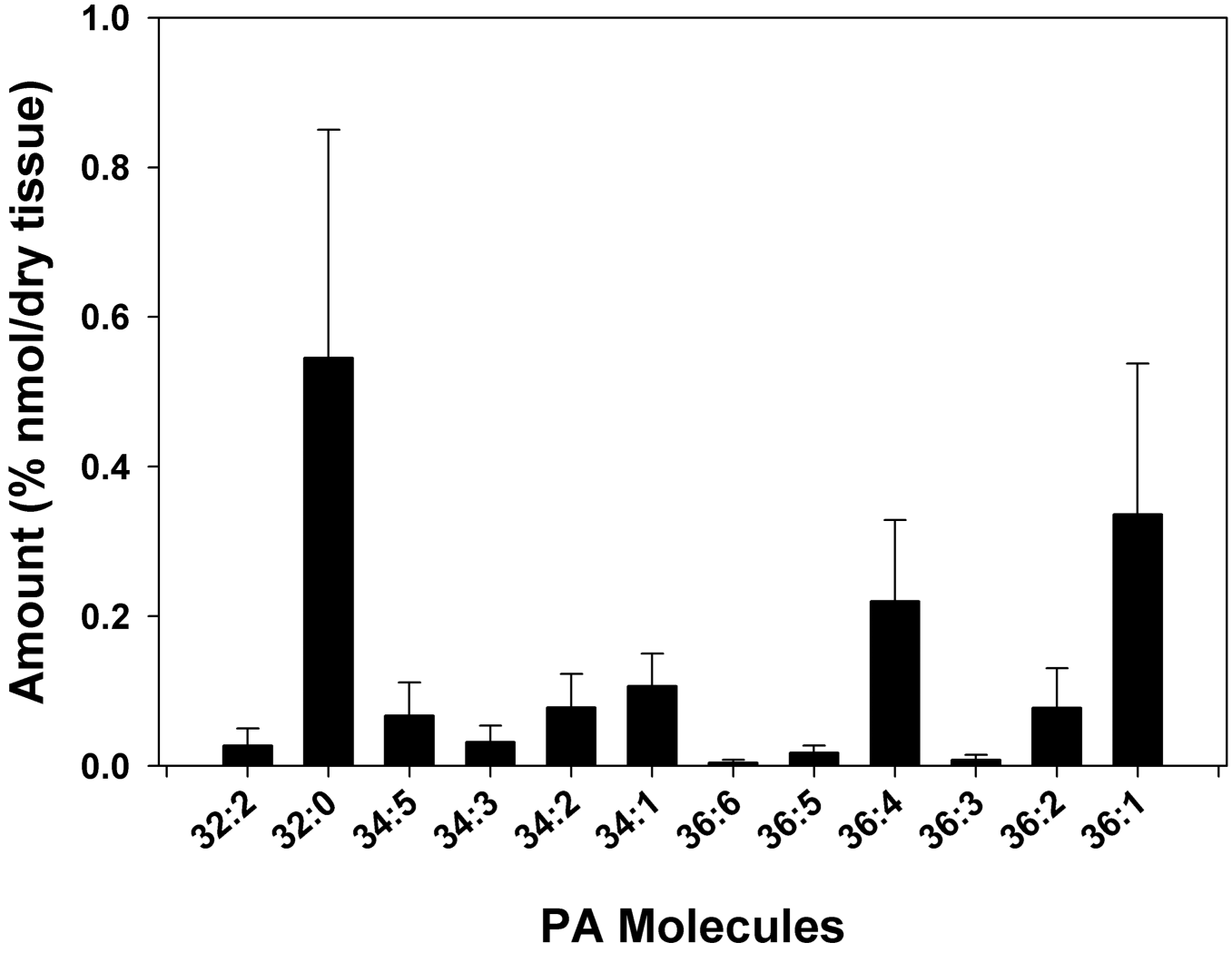


**Fig. 6.**

Percentage of phosphatidic acid in *Lasiurus borealis* hair, (Amounts nmol/dry tissue weight, Means±S.E.).

**Table 1**

Mass, elemental composition, and name of glycerophospholipid $NH_4^+$ adducts found on the surface of *Lasiurus borealis* hair.

| Lysophosphatidylcholine | | | Phosphatidylcholine | | | Phosphatidylethanolamine | | |
|---|---|---|---|---|---|---|---|---|
| **Mass** | **Elemental Composition** | **Name** | **Mass** | **Elemental Composition** | **Name** | **Mass** | **Elemental Composition** | **Name** |
| 466.3 | $C_{22}H_{44}O_7PN$ | LPC(14:1) | 648.5 | $C_{34}H_{66}O_8PN$ | PC(26:1) | 690.5 | $C_{37}H_{72}O_8PN$ | PE(32:1) |
| 468.3 | $C_{22}H_{46}O_7PN$ | LPC(14:0) | 650.5 | $C_{34}H_{68}O_8PN$ | PC(26:0) | 692.5 | $C_{37}H_{74}O_8PN$ | PE(32:0) |
| 480.3 | $C_{23}H_{46}O_7PN$ | LPC(15:1) | 676.5 | $C_{36}H_{70}O_8PN$ | PC(28:1) | 702.5 | $C_{38}H_{72}O_8PN$ | PE(33:2) |
| 482.3 | $C_{23}H_{48}O_7PN$ | LPC(15:0) | 678.5 | $C_{36}H_{72}O_8PN$ | PC(28:0) | 704.5 | $C_{38}H_{74}O_8PN$ | PE(33:1) |
| 494.3 | $C_{24}H_{48}O_7PN$ | LPC(16:1) | 702.5 | $C_{38}H_{72}O_8PN$ | PC(30:2) | 714.5 | $C_{39}H_{72}O_8PN$ | PE(34:3) |
| 496.3 | $C_{24}H_{50}O_7PN$ | LPC(16:0) | 704.5 | $C_{38}H_{74}O_8PN$ | PC(30:1) | 716.5 | $C_{39}H_{74}O_8PN$ | PE(34:2) |
| 508.3 | $C_{25}H_{50}O_7PN$ | LPC(17:1) | 706.5 | $C_{38}H_{76}O_8PN$ | PC(30:0) | 718.5 | $C_{39}H_{76}O_8PN$ | PE(34:1) |
| 510.4 | $C_{25}H_{52}O_7PN$ | LPC(17:0) | 716.5 | $C_{39}H_{74}O_8PN$ | PC(31:2) | 720.5 | $C_{39}H_{78}O_8PN$ | PE(34:0) |
| 520.3 | $C_{26}H_{50}O_7PN$ | LPC(18:2) | 718.5 | $C_{39}H_{76}O_8PN$ | PC(31:1) | 730.5 | $C_{40}H_{76}O_8PN$ | PE(35:2) |
| 522.4 | $C_{26}H_{52}O_7PN$ | LPC(18:1) | 720.5 | $C_{39}H_{78}O_8PN$ | PC(31:0) | 732.5 | $C_{40}H_{78}O_8PN$ | PE(35:1) |
| 524.4 | $C_{26}H_{54}O_7PN$ | LPC(18:0) | 730.5 | $C_{40}H_{76}O_8PN$ | PC(32:2) | 736.5 | $C_{41}H_{70}O_8PN$ | PE(36:6) |
| **Lysophosphatidylethanolamine** | | | 732.5 | $C_{40}H_{78}O_8PN$ | PC(32:1) | 738.5 | $C_{41}H_{72}O_8PN$ | PE(36:5) |
| 424.2 | $C_{19}H_{38}O_7PN$ | LPE(14:1) | 734.6 | $C_{40}H_{80}O_8PN$ | PC(32:0) | 742.5 | $C_{41}H_{76}O_8PN$ | PE(36:3) |
| 438.3 | $C_{20}H_{40}O_7PN$ | LPE(15:1) | 744.5 | $C_{41}H_{78}O_8PN$ | PC(33:2) | 744.5 | $C_{41}H_{78}O_8PN$ | PE(36:2) |
| 440.3 | $C_{20}H_{42}O_7PN$ | LPE(15:0) | 746.6 | $C_{41}H_{80}O_8PN$ | PC(33:1) | 746.6 | $C_{41}H_{80}O_8PN$ | PE(36:1) |
| 452.3 | $C_{21}H_{42}O_7PN$ | LPE(16:1) | 748.6 | $C_{41}H_{82}O_8PN$ | PC(33:0) | 758.6 | $C_{42}H_{80}O_8PN$ | PE(37:2) |
| 454.3 | $C_{21}H_{44}O_7PN$ | LPE(16:0) | 754.5 | $C_{42}H_{76}O_8PN$ | PC(34:4) | 760.6 | $C_{42}H_{82}O_8PN$ | PE(37:1) |
| 468.3 | $C_{22}H_{46}O_7PN$ | LPE(17:0) | 756.5 | $C_{42}H_{78}O_8PN$ | PC(34:3) | 762.6 | $C_{42}H_{84}O_8PN$ | PE(37:0) |
| 478.3 | $C_{23}H_{44}O_7PN$ | LPE(18:2) | 758.6 | $C_{42}H_{80}O_8PN$ | PC(34:2) | 770.6 | $C_{43}H_{80}O_8PN$ | PE(38:3) |
| 480.3 | $C_{23}H_{46}O_7PN$ | LPE(18:1) | 760.6 | $C_{42}H_{82}O_8PN$ | PC(34:1) | 772.6 | $C_{43}H_{82}O_8PN$ | PE(38:2) |
| 508.3 | $C_{25}H_{50}O_7PN$ | LPE(20:1) | 778.5 | $C_{44}H_{76}O_8PN$ | PC(36:6) | 774.6 | $C_{43}H_{84}O_8PN$ | PE(38:1) |
| 510.4 | $C_{25}H_{52}O_7PN$ | LPE(20:0) | 780.5 | $C_{44}H_{78}O_8PN$ | PC(36:5) | 776.6 | $C_{43}H_{86}O_8PN$ | PE(38:0) |
| **Phosphatidylglycerol** | | | 782.6 | $C_{44}H_{80}O_8PN$ | PC(36:4) | 800.6 | $C_{45}H_{86}O_8PN$ | PE(40:2) |

| Lysophosphatidylcholine | | | Phosphatidylcholine | | | Phosphatidylethanolamine | | |
|---|---|---|---|---|---|---|---|---|
| **Mass** | **Elemental Composition** | **Name** | **Mass** | **Elemental Composition** | **Name** | **Mass** | **Elemental Composition** | **Name** |
| 710.5 | $C_{36}H_{69}O_{10}P$ | PG(30:1) | 784.6 | $C_{44}H_{82}O_8PN$ | PC(36:3) | 824.6 | $C_{47}H_{86}O_8PN$ | PE(42:4) |
| 712.5 | $C_{36}H_{71}O_{10}P$ | PG(30:0) | 786.6 | $C_{44}H_{84}O_8PN$ | PC(36:2) | 826.6 | $C_{47}H_{88}O_8PN$ | PE(42:3) |
| **Phosphatidylglycerol** | | | **Phosphatidylcholine** | | | **Phosphatidylethanolamine** | | |
| 738.5 | $C_{38}H_{73}O_{10}P$ | PG(32:1) | 788.6 | $C_{44}H_{86}O_8PN$ | PC(36:1) | 828.6 | $C_{47}H_{90}O_8PN$ | PE(42:2) |
| 740.5 | $C_{38}H_{75}O_{10}P$ | PG(32:0) | 806.6 | $C_{46}H_{80}O_8PN$ | PC(38:6) | **Phosphatidylserine** | | |
| 760.5 | $C_{40}H_{71}O_{10}P$ | PG(34:4) | 808.6 | $C_{46}H_{82}O_8PN$ | PC(38:5) | 732.5 | $C_{38}H_{70}O_{10}PN$ | PS(32:2) |
| 762.5 | $C_{40}H_{73}O_{10}P$ | PG(34:3) | 810.6 | $C_{46}H_{84}O_8PN$ | PC(38:4) | 734.5 | $C_{38}H_{72}O_{10}PN$ | PS(32:1) |
| 764.5 | $C_{40}H_{75}O_{10}P$ | PG(34:2) | 812.6 | $C_{46}H_{86}O_8PN$ | PC(38:3) | 746.5 | $C_{39}H_{72}O_{10}PN$ | PS(33:2) |
| 766.5 | $C_{40}H_{77}O_{10}P$ | PG(34:1) | 814.6 | $C_{46}H_{88}O_8PN$ | PC(38:2) | 750.5 | $C_{39}H_{76}O_{10}PN$ | PS(33:0) |
| 768.5 | $C_{40}H_{79}O_{10}P$ | PG(34:0) | 836.6 | $C_{48}H_{86}O_8PN$ | PC(40:5) | 756.5 | $C_{40}H_{70}O_{10}PN$ | PS(34:4) |
| 788.5 | $C_{42}H_{75}O_{10}P$ | PG(36:4) | 840.6 | $C_{48}H_{90}O_8PN$ | PC(40:3) | 760.5 | $C_{40}H_{74}O_{10}PN$ | PS(34:2) |
| 790.5 | $C_{42}H_{77}O_{10}P$ | PG(36:3) | 842.7 | $C_{48}H_{92}O_8PN$ | PC(40:2) | 762.5 | $C_{40}H_{76}O_{10}PN$ | PS(34:1) |
| 792.5 | $C_{42}H_{79}O_{10}P$ | PG(36:2) | **Phosphatidylinositol** | | | 764.5 | $C_{40}H_{78}O_{10}PN$ | PS(34:0) |
| 794.6 | $C_{42}H_{81}O_{10}P$ | PG(36:1) | 744.4 | $C_{35}H_{67}O_{13}P$ | PI(26:0) | 774.5 | $C_{41}H_{76}O_{10}PN$ | PS(35:2) |
| 812.5 | $C_{44}H_{75}O_{10}P$ | PG(38:6) | 772.5 | $C_{37}H_{71}O_{13}P$ | PI(28:0) | 775.5 | $C_{41}H_{77}O_{10}PN$ | PS(35:1) |
| 814.5 | $C_{44}H_{77}O_{10}P$ | PG(38:5) | 798.5 | $C_{39}H_{73}O_{13}P$ | PI(30:1) | 778.6 | $C_{41}H_{80}O_{10}PN$ | PS(35:0) |
| **Phosphatidic acid** | | | 800.5 | $C_{39}H_{75}O_{13}P$ | PI(30:0) | 788.5 | $C_{42}H_{78}O_{10}PN$ | PS(36:2) |
| 662.4 | $C_{35}H_{65}O_8P$ | PA(32:2) | 814.5 | $C_{40}H_{77}O_{13}P$ | PI(31:0) | 790.6 | $C_{42}H_{80}O_{10}PN$ | PS(36:1) |
| 666.5 | $C_{35}H_{69}O_8P$ | PA(32:0) | 824.5 | $C_{41}H_{75}O_{13}P$ | PI(32:2) | 814.6 | $C_{44}H_{80}O_{10}PN$ | PS(38:3) |
| 684.4 | $C_{37}H_{63}O_8P$ | PA(34:5) | 826.5 | $C_{41}H_{77}O_{13}P$ | PI(32:1) | 816.6 | $C_{44}H_{82}O_{10}PN$ | PS(38:2) |
| 688.5 | $C_{37}H_{67}O_8P$ | PA(34:3) | 828.5 | $C_{41}H_{79}O_{13}P$ | PI(32:0) | 818.6 | $C_{44}H_{84}O_{10}PN$ | PS(38:1) |
| 690.5 | $C_{37}H_{69}O_8P$ | PA(34:2) | 840.5 | $C_{42}H_{79}O_{13}P$ | PI(33:1) | 844.6 | $C_{46}H_{86}O_{10}PN$ | PS(40:2) |
| 692.5 | $C_{37}H_{71}O_8P$ | PA(34:1) | 842.5 | $C_{42}H_{81}O_{13}P$ | PI(33:0) | 846.6 | $C_{46}H_{88}O_{10}PN$ | PS(40:1) |

| Lysophosphatidylcholine | | | Phosphatidylcholine | | | Phosphatidylethanolamine | | |
|---|---|---|---|---|---|---|---|---|
| **Mass** | **Elemental Composition** | **Name** | **Mass** | **Elemental Composition** | **Name** | **Mass** | **Elemental Composition** | **Name** |
| 710.4 | $C_{39}H_{65}O_8P$ | PA(36:6) | 850.5 | $C_{43}H_{77}O_{13}P$ | PI(34:3) | 872.6 | $C_{48}H_{90}O_{10}PN$ | PS(42:2) |
| 712.5 | $C_{39}H_{67}O_8P$ | PA(36:5) | 852.5 | $C_{43}H_{79}O_{13}P$ | PI(34:2) | 874.6 | $C_{48}H_{92}O_{10}PN$ | PS(42:1) |
| 714.5 | $C_{39}H_{69}O_8P$ | PA(36:4) | 854.5 | $C_{43}H_{81}O_{13}P$ | PI(34:1) | 900.7 | $C_{50}H_{94}O_{10}PN$ | PS(44:2) |
| 716.5 | $C_{39}H_{71}O_8P$ | PA(36:3) | 868.6 | $C_{44}H_{83}O_{13}P$ | PI(35:1) | | | |
| 718.5 | $C_{39}H_{73}O_8P$ | PA(36:2) | 872.5 | $C_{45}H_{75}O_{13}P$ | PI(36:6) | | | |
| 720.5 | $C_{39}H_{75}O_8P$ | PA(36:1) | 876.5 | $C_{45}H_{79}O_{13}P$ | PI(36:4) | | | |
| | | | 878.5 | $C_{45}H_{81}O_{13}P$ | PI(36:3) | | | |
| | | | 880.6 | $C_{45}H_{83}O_{13}P$ | PI(36:2) | | | |
| | | | 882.6 | $C_{45}H_{85}O_{13}P$ | PI(36:1) | | | |
| | | | 908.6 | $C_{47}H_{87}O_{13}P$ | PI(38:2) | | | |
| | | | 910.6 | $C_{47}H_{89}O_{13}P$ | PI(38:1) | | | |
| | | | 912.6 | $C_{47}H_{91}O_{13}P$ | PI(38:0) | | | |